Defire
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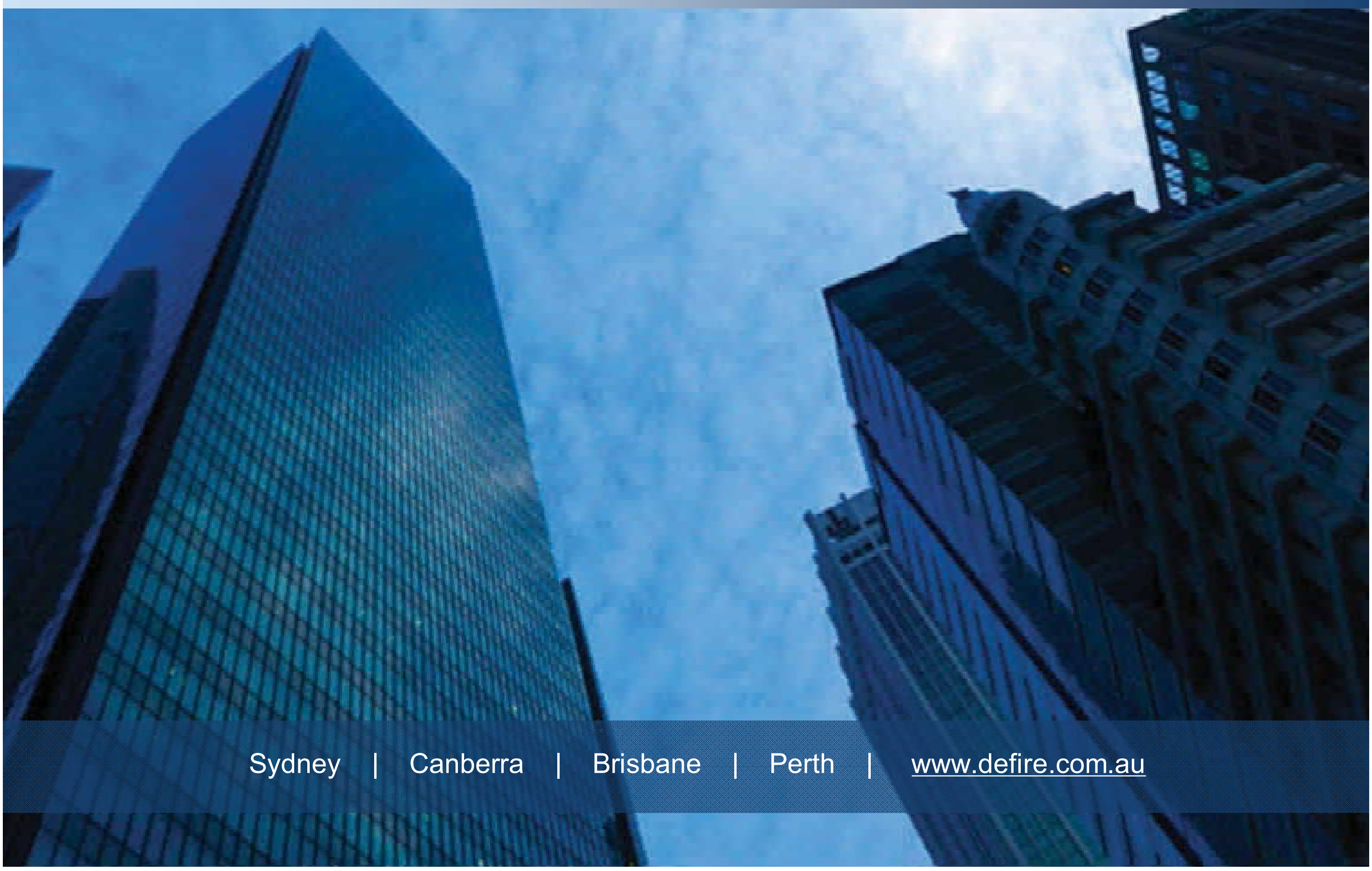
Alternative solution report

GL Investment Co

161 Sussex St, Sydney – Four Points by Sheraton

SY130111

Revision R1.0 | 17 April 2014



Amendment schedule

Version	Date	Information relating to report			
R1.0	16/04/2014	Reason for issue	Report issued to GL Investment Co, Savills Project Management, Brookfield Multiplex, Cox Architecture, Bates Smart, AECOM, Aurecon, Taylor Thomson Whitting and Philip Chun for review and comment.		
			Prepared by	Reviewed by	Approved by
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Executive summary

This alternative solution report documents the findings of a fire safety engineering assessment undertaken to determine whether the proposed redevelopment at 161 Sussex St, Sydney – Four Points by Sheraton complies with the relevant performance requirements of the National Construction Code Series 2013 Volume One – Building Code of Australia (BCA)[1]. Defire undertook the assessment in accordance with the International Fire Engineering Guidelines (IFEG)[2] at the request of GL Investment Co.

The redevelopment works involve the refurbishment and extension of the existing podium levels and the construction of a new 24 storey tower. The new tower will be located above the extended podium adjoining the southern portion of the existing building.

The existing building currently straddles the Western Distributor roadway. The extended portion of the podium will be located above the Western Distributor roadway forming an underpass. This portion of the building will contain meeting rooms and function rooms on the ground and mezzanine floors. The new tower will contain hotel offices on level 1, residential on levels 2 to 15, plant areas on level 16 and 24, and commercial on levels 17 to 23.

The fire engineering strategy associated with the Western Distributor underpass formed as a result of the redevelopment works is documented in a separate fire engineering report (FER) SY130111 WD Underpass FER1.1 dated 4 December 2013 prepared by Defire. This alternative solution report for the Four Points by Sheraton building is to be read in conjunction with the FER for the Western Distributor underpass.

The design of the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower includes areas which do not comply with the deemed-to-satisfy (DTS) provisions of the BCA. Table 1 describes the BCA requirements associated with the alternative solutions.

No	Description of alternative solutions	DTS provision	Performance requirements (A0.10)	Method of meeting performance requirements	Assessment method
1.	The maximum travel distances within fire compartment 1 on the lower ground, ground and mezzanine floors are: • Up to 25m to a point of choice to two alternative exits in lieu of 20m • Up to 60m to the nearest of two exits in lieu of 40m • Up to 90m between alternative exits in lieu of 60m	Clauses D1.4 and D1.5	DP4 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
	A performance-based smoke hazard management system is proposed in the circulation areas on the lower ground, ground and mezzanine floors of the hotel including: • Smoke exhaust inlet locations and quantities • Omission of smoke exhaust from all day dining restaurant and back of house areas	NSW table E2.2b and specification E2.2b			

[1] National Construction Code Series 2013, Volume One – Building Code of Australia, Australian Building Codes Board, Australia.
[2] International Fire Engineering Guidelines – Edition 2005, Australian Building Codes Board, Australia.

No	Description of alternative solutions	DTS provision	Performance requirements (A0.10)	Method of meeting performance requirements	Assessment method
2.	The maximum travel distances within the northern ground floor and mezzanine floors proposed are: • Up to 30m to a point of choice to two alternative exits in lieu of 20m • Up to 50m to the nearest of two exits in lieu of 40m	Clauses D1.4 and D1.5	DP4 and EP2.2	Equivalent to DTS A0.5(b)(ii)	Comparison to DTS A0.9(c)
3.	The mezzanine floor is provided with an aggregate exit width of 13m in lieu of 18m.	Clause D1.6	DP4, DP6 and EP2.2	Equivalent to DTS A0.5(b)(ii)	Comparison to DTS A0.9(c)
4.	Travel distances from the sole-occupancy units in the hotel tower on levels 2 to 15 are up to 8m to a point of choice in lieu of 6m.	Clause D1.4	DP4 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
5.	The maximum fire rating for the class 6 all day dining restaurant and kitchen areas on the ground floor is reduced from 180 minutes to 120 minutes.	Clauses C1.1, C2.8, C2.9 and specification C1.1	CP1 and CP2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
6.	The fire control room is accessible from a single door, direct from the front entrance of the site in lieu of two accessible paths.	Clause E1.8 and specification E1.8	EP1.6	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
7.	The point of discharge of fire isolated stair 3 is in the northern ground floor lobby, within the confines of the building. An alternative discharge location is also provided on the lower ground floor at the bus parking bays on Slip Street.	Clause D1.7	CP2, DP4, DP5 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
8.	The point of discharge of fire isolated stair 2 is in the main ground floor lobby, within the confines of the building	Clause D1.7	CP2, DP4, DP5 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
9.	The roof trusses forming the roof structure of the northern and southern convention rooms on the mezzanine floor are to be constructed with steel in lieu of achieving the required FRL of 120/-/-. The trusses will be lined on the underside with a fire protective covering.	Clause C1.1 and specification C1.1	CP1	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
10.	The Wharf Lane bridge is to be constructed with a steel structure and timber floor in lieu of achieving the required FRL of 120/-/- and 120/120/120 respectively.	Clause C1.1 and specification C1.1	CP1	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)

Table 1 BCA requirements associated with the alternative solutions

The fire safety engineering assessment undertaken found that the design of the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower achieves compliance with the relevant performance requirements of the BCA, subject to the following recommendations:

- This report and the fire safety measures listed in section 5 must be implemented into the design and identified on the fire safety schedule for the building. They must be maintained and certified in accordance with the Environmental Planning and Assessment Regulations 2000 and relevant Australian standards.
- If there are building alterations or additions, a change in use or changes to the fire safety system in the future, a reassessment will be needed to verify consistency with the assessment contained in this report.

Contents

1. Introduction

This alternative solution report documents the findings of a fire safety engineering assessment undertaken to determine whether the proposed redevelopment at 161 Sussex St, Sydney – Four Points by Sheraton complies with the relevant performance requirements of the National Construction Code Series 2013 Volume One – Building Code of Australia (BCA)[3]. Defire undertook the assessment in accordance with the International Fire Engineering Guidelines (IFEG)[4] at the request of GL Investment Co.

The redevelopment works involve the refurbishment and extension of the existing podium levels and the construction of a new 24 storey tower. The new tower will be located above the extended podium adjoining the southern portion of the existing building. The extended podium will result in the building being located over the Western Distributor roadway forming an underpass. The fire engineering strategy associated with the underpass is documented in a separate fire engineering report (FER) SY130111 WD Underpass FER1.1 dated 4 December 2013 prepared by Defire. This alternative solution report for the Four Points by Sheraton building is to be read in conjunction with the FER for the Western Distributor underpass.

This alternative solution report relates to the design of the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower. The new southern tower is fire separated from the existing southern portion of the hotel from level 1 and upwards and considered as a separate fire compartment. The new commercial lift lobby within the new southern tower is fire separated from the redeveloped ground floor of the hotel.

2. Fire engineering brief

The purpose of the fire engineering brief (FEB) is to consult with the relevant stakeholders to define the scope of the project, to agree upon the objectives, fire safety measures, methods of analysis and acceptance criteria for the alternative solutions. The IFEG states that the scope of the project and the method by which it will receive regulatory approval dictates the extent of the FEB process required.

The proposed alternative solutions have been discussed with the design team and the certifying authority at regular meetings conducted every 2 – 4 weeks since May 2013 which are formally minuted.

On this basis, a written FEB questionnaire (FEBQ) V01 was submitted to Fire and Rescue NSW (FRNSW) on 29 August 2013. The purpose of this FEBQ was to request a meeting with FRNSW with the intention to discuss the proposed alternative solutions and methodology prior to preparing an alternative solution report for the project.

FEBQ V01.1 was being prepared to resubmit to FRNSW which included additional alternative solutions that had arisen during the design phase. Prior to its formal submission, the meeting request with FRNSW was granted.

A FEB meeting was held at Defire's office on 12 February 2014 to review the proposed alternative solutions with the relevant stakeholders. FEBQ V01.1 formed the basis of the discussions. At the end of the meeting it was generally agreed that the proposed design and alternative solutions were suitable for detailed analysis. FRNSW requested that Defire formally submit FEBQ V01.1 for their written comment. FEBQ V01.1 was submitted to FRNSW on 5 March 2014.

The comments from FRNSW in FEBQ V02 were received on 20 March 2014. Their comments and Defire's response are attached in Appendix B.

The draft alternative solution report was submitted to the stakeholders identified in Table 2 – with the exception of the fire brigade – for further comment after the detailed analysis had been completed. The final alternative solution report will be referred to Fire and Rescue NSW by the certifying authority for comment.

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[3] National Construction Code Series 2013, Volume One – Building Code of Australia, Australian Building Codes Board, Australia.
[4] International Fire Engineering Guidelines – Edition 2005, Australian Building Codes Board, Australia.

The relevant stakeholders identified for this project are listed in Table 2.

Name	Role	Organisation	Contact details
Jenny Watt	Client	GL Investment Co	02 9223 0350
Adam Thomas	Project manager	Savills Project Management	02 8215 8888
Kristina Stoffers Peter Jennings	Builder	Brookfield Multiplex	02 9322 2000
Ramin Jahromi Michael Bradburn	Architect	Cox Architecture	02 9267 9599
Torsten Fiedler	Interior Architect	Bates Smart	02 8354 5100
Dan Kirk	Fire services engineer	Aurecon	02 9465 5599
Richard Spiteri Shaohua Xia	Fire brigade	Fire & Rescue NSW (FRNSW)	02 9742 7400
Frank de Pasquale	Certifying authority representative	Philip Chun	02 9412 2322
Robert Marinelli	Certifying authority A1 – BPB 250	Philip Chun	02 9412 2322
Jack Tam	Fire safety engineer	Defire	02 9211 4333
Jason Jeffress	Accredited fire safety engineer C10 – BPB 197	Defire	02 9211 4333

Table 2 Stakeholders

The proposed design documented in this report is consistent with the information presented to the stakeholders during the FEB process with the exception that alternative solution 1 noted in FEBQ V02 has been split into three separate alternative solutions for clarity. This is because they involve different assessment methodologies. The alternative solutions are documented as alternative solutions 1, 2 and 3 of this report.

3. Description of the building and alternative solutions

3.1 Building description

The project involves the redevelopment of the existing 17 storey Four Points by Sheraton hotel. The existing building contains the hotel lobby, retail, dining and function rooms on the ground floor, back-of-house areas on the mezzanine floor and residential on levels 1 to 14. The lower ground floor contains a foyer area, back-of-house areas and a loading dock connected to Slip Street.

The redevelopment works involve the refurbishment and extension of the existing podium levels and the construction of a new 24 storey tower. The new tower will be located above the extended podium adjoining the southern portion of the existing building.

The existing building currently straddles the Western Distributor roadway. The extended portion of the podium will be located above the Western Distributor roadway and contain meeting rooms and function rooms on the ground and mezzanine floors. The new tower will contain hotel offices on level 1, residential on levels 2 to 15, plant areas on level 16 and 24, and commercial on levels 17 to 23. A perspective view of the proposed redevelopment and site plan is shown in Figure 1 and Figure 2.

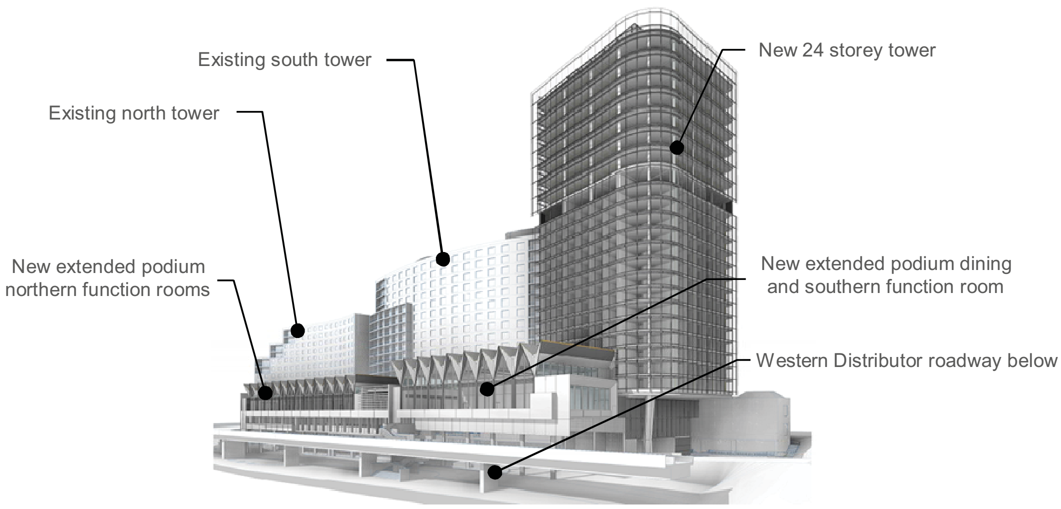


Figure 1 South west perspective view of proposed development

This alternative solution report relates to the design of the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower. This report excludes the existing south and north towers.

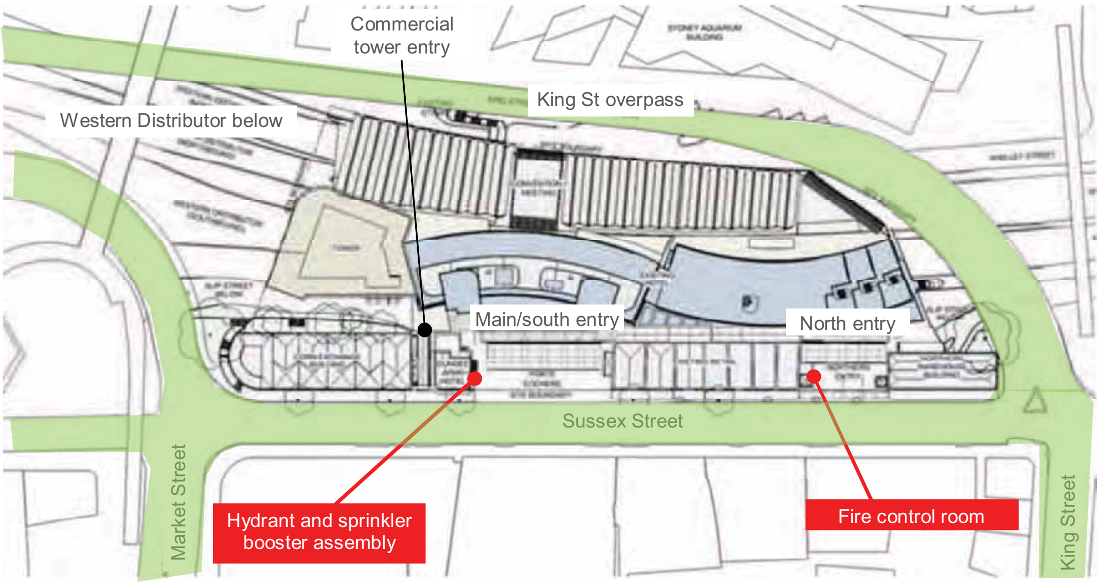


Figure 2 Site plan

A description of the main characteristics of the building for the purpose of determining compliance with the BCA is given in Table 3 [5]. The proposed use and classification of the building or part in accordance with clause A3.2 of the BCA is described in Table 4.

Characteristic	BCA clause	Description
Effective height	A1.1	Greater than 50m
Type of construction required	C1.1	Type A
Rise in storeys	C1.2	27
Levels contained	-	27

Table 3 Main building characteristics

Part of building	Use	Classification (A3.2)
Lower ground	Hotel lobby, loading dock,, back of house, office and storage	Class 3, 5, 7a, 7b and 9b
Ground	Hotel lobby, function rooms, retail and restaurant	Class 3, 5, 6 and 9b
Mezzanine	Function rooms, kitchen and hotel back of house	Class 3, 5 and 9b
Level 1	Hotel rooms, gym and hotel offices	Class 3
Level 2 to 15	Hotel rooms	Class 3
Level 17 to 23	Commercial office	Class 5
Level 12 and 24	Plant	Class 3 and 5 ancillary

Table 4 Use and classification

[5] Philip Chun Building Surveying, 20 May 2013, BCA assessment report, report number N13-201181 revision R01a.

3.2 Preventative and protective measures

The fire safety measures provided in the existing building are listed on the fire safety statement attached in Appendix C. The redeveloped and new portions of the building will be provided with the major fire safety measures required by the DTS provisions of the BCA listed as follows[6]. A comprehensive list of fire safety measures is to be provided by the certifier as part of the building approval process. Additional fire safety measures required as part of the alternative solution are listed within section 5.

- Automatic shutdown of mechanical air handling systems
- Automatic sprinkler system
- Automatically opening exit doors
- Emergency evacuation plan
- Emergency lifts
- Emergency lighting
- Exit signs
- Fire control room
- Fire curtains
- Fire doors
- Fire hose reel system
- Fire hydrant system
- Fire rated construction
- Portable fire extinguishers
- Smoke curtains
- Smoke detection system
- Smoke doors
- Smoke exhaust system in the main lobby and heritage void
- Sound system and intercom systems for emergency purposes
- Stair pressurising system in fire stairs
- Stand-by power systems
- Zone smoke control system on commercial floors

3.3 Occupant characteristics

The characteristics of the occupants expected to be in the building are listed in Table 5.

Characteristic	Description
Familiarity	Hotel rooms – Occupants in the hotel are expected to be short-term residents or transient visitors who may not be familiar with the building layout and exit locations. Staff are also expected to be present which are familiar with the layout of the building and the emergency procedures. Office levels – Occupants are expected to be staff who are familiar with the layout of the building. Hotel podium, restaurant, function rooms - Occupants are expected to be primarily patrons who may not be familiar with the layout of the building and location of fire exits. Staff are also expected to be present who are familiar with the layout of the building and the emergency procedures.
Awareness	Hotel rooms – Occupants may be asleep at the time of a fire which could delay their response time for evacuation. Office levels – Occupants are expected to be awake and alert to a potential emergency event such as a fire in the building. Hotel podium, restaurant, function rooms – Occupants are expected to be awake and alert to a potential emergency event such as a fire in the building. Some occupants may be focused on a performance and / or under the influence of alcohol.
Mobility	Occupants are assumed to have the same level of mobility as the general population. This may include a limited proportion of mobility impaired occupants. These occupants may require crutches, a wheelchair or similar to evacuate on their own or need assistance from other occupants.
Age	Occupants of all ages may be present within the building.
Language	Although occupants may have English as their second language, they are expected to understand signs and verbal instructions in English to the degree necessary to not adversely impact upon evacuation.

[6] Certifier to confirm essential services systems.

Characteristic	Description
Occupant load	Population densities used in this assessment are based upon population estimates provided by Bates Smart[7] and GL Investment Co[8]. The populations are based on the following: **Lower ground floor** • Lobby: 58 persons **Ground floor** • Ground floor all day dining: 340 persons • Main lobby lounge: 45 persons • Ground floor bar: 104 persons • Northern lounge: 7 persons • Ground floor meeting rooms 1-5 total: 356 persons (based on 1m^2/person) • Meeting rooms 6-9: 18 persons each • Meeting rooms 10-11: 15 persons each **Ground floor total:** Maximum 1011 persons comprising 954 patrons and 57 staff **Mezzanine floor** • Northern function room: 1000 persons – see note 1 below • Southern function room: 1100 persons – see note 1 below • Southern pre-function room: 505 persons – see note 1 below • Northern pre-function room: 5054 persons – see note 1 below **Mezzanine floor total:** Maximum 1800 persons comprising 1600 patrons and 200 staff **Note 1:** The maximum permissible population within either function room is subject to restrictions on the use of the adjacent function room to maintain the total population on the mezzanine floor below 1800 persons – including staff. It has also been assumed that the pre-function rooms are associated with the corresponding function rooms. As such, when the function rooms are fully occupied, the pre-function rooms are likely to contain minimal people.

Table 5 Occupant characteristics

[7] Bates Smart markup, 161 Sussex Street – GF pax. 29 November 2013.
[8] GL Investment Co. Aconex GLIM-CA-000075 dated 13 December 2013.

3.4 Alternative solutions

The design of the building includes areas that do not comply with the DTS provisions of the BCA. We intend to use a performance-based fire safety engineering approach to develop alternative solutions to the DTS provisions of the BCA. Table 6 describes the BCA requirements associated with the alternative solutions.

<table>
<tr><th>No</th><th>Description of alternative solutions</th><th>DTS provision</th><th>Performance requirements (A0.10)</th><th>Method of meeting performance requirements</th><th>Assessment method</th></tr>
<tr><td rowspan="2">1.</td><td>The maximum travel distances within fire compartment 1 on the lower ground, ground and mezzanine floors are:
• Up to 25m to a point of choice to two alternative exits in lieu of 20m
• Up to 60m to the nearest of two exits in lieu of 40m
• Up to 90m between alternative exits in lieu of 60m</td><td>Clauses D1.4 and D1.5</td><td rowspan="2">DP4 and EP2.2</td><td rowspan="2">Complies with performance requirements A0.5(b)(i)</td><td rowspan="2">Verification method A0.9(b)(ii)</td></tr>
<tr><td>A performance-based smoke hazard management system is proposed in the circulation areas on the lower ground, ground and mezzanine floors of the hotel including:
• Smoke exhaust inlet locations and quantities
• Omission of smoke exhaust from all day dining restaurant and back of house areas</td><td>NSW table E2.2b and specification E2.2b</td></tr>
<tr><td>2.</td><td>The maximum travel distances within the northern ground floor and mezzanine floors proposed are:
• Up to 30m to a point of choice to two alternative exits in lieu of 20m
• Up to 50m to the nearest of two exits in lieu of 40m</td><td>Clauses D1.4 and D1.5</td><td>DP4 and EP2.2</td><td>Equivalent to DTS A0.5(b)(ii)</td><td>Comparison to DTS A0.9(c)</td></tr>
<tr><td>3.</td><td>The mezzanine floor is provided with an aggregate exit width of 13m in lieu of 18m.</td><td>Clause D1.6</td><td>DP4, DP6 and EP2.2</td><td>Equivalent to DTS A0.5(b)(ii)</td><td>Comparison to DTS A0.9(c)</td></tr>
<tr><td>4.</td><td>Travel distances from the sole-occupancy units in the hotel tower on levels 2 to 15 are up to 8m to a point of choice in lieu of 6m.</td><td>Clause D1.4</td><td>DP4 and EP2.2</td><td>Complies with performance requirements A0.5(b)(i)</td><td>Verification method A0.9(b)(ii)</td></tr>
<tr><td>5.</td><td>The maximum fire rating for the class 6 all day dining restaurant and kitchen areas on the ground floor is reduced from 180 minutes to 120 minutes.</td><td>Clauses C1.1, C2.8, C2.9 and specification C1.1</td><td>CP1 and CP2</td><td>Complies with performance requirements A0.5(b)(i)</td><td>Verification method A0.9(b)(ii)</td></tr>
</table>

No	Description of alternative solutions	DTS provision	Performance requirements (A0.10)	Method of meeting performance requirements	Assessment method
6.	The fire control room is accessible from a single door, direct from the front entrance of the site in lieu of two accessible paths.	Clause E1.8 and specification E1.8	EP1.6	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
7.	The point of discharge of fire isolated stair 3 is in the northern ground floor lobby, within the confines of the building. An alternative discharge location is also provided on the lower ground floor at the bus parking bays on Slip Street.	Clause D1.7	CP2, DP4, DP5 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
8.	The point of discharge of fire isolated stair 2 is in the main ground floor lobby, within the confines of the building	Clause D1.7	CP2, DP4, DP5 and EP2.2	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
9.	The roof trusses forming the roof structure of the northern and southern convention rooms on the mezzanine floor are to be constructed with steel in lieu of achieving the required FRL of 120/-/-. The trusses will be lined on the underside with a fire protective covering.	Clause C1.1 and specification C1.1	CP1	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)
10.	The Wharf Lane bridge is to be constructed with a steel structure and timber floor in lieu of achieving the required FRL of 120/-/- and 120/120/120 respectively.	Clause C1.1 and specification C1.1	CP1	Complies with performance requirements A0.5(b)(i)	Verification method A0.9(b)(ii)

Table 6 BCA requirements associated with the alternative solutions

4. Scope, objective and assumptions

4.1 Scope and objective

- The scope of this report is limited to the alternative solutions described in section 3.4.
- The objective of this report is to demonstrate compliance with the fire safety aspects of the performance requirements of the BCA. Matters such as property protection (other than protection of adjoining property), business interruption, public perception, environmental impacts and broader community issues – such as loss of a major employer and impact on tourism – have not been considered as they are outside the scope of the BCA.
- This report considers single point arson as a source of ignition. Arson involving accelerants or multiple ignition sources is not considered in this assessment as it is outside the scope of the BCA.
- The scope of our works is limited to considering evacuation and fire safety issues for people with disabilities to the same degree as the DTS provisions of the BCA. Specifically, consideration of evacuation from the building by people with disabilities under the provisions of the Disability Discrimination Act 1992 is excluded.
- If there are building alterations or additions, a change in use or changes to the fire safety systems in the future, a reassessment will be needed to verify consistency with the assessment in this report.
- The data, methodologies, calculations and conclusions documented within this report specifically relate to the building and must not be used for any other purpose.
- The documentation that forms the basis for this report is listed within Appendix A.
- This report has been prepared based upon information provided by others. Defire has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated into this report as a result.

4.2 Assumptions

- The existing building complies with the applicable building standard at the time of construction. All new works associated with the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower comply with the current DTS provisions of the BCA except for the specific alternative solutions described within section 3.4.
- All of the fire safety systems are assumed to be designed, installed and operate in accordance with the appropriate Australian standards, other design codes, legislation and regulations relevant to the project unless specifically stated otherwise.
- For a satisfactory level of fire safety to be achieved, regular testing and maintenance of all fire safety systems and measures, including management-in-use systems, is essential and is assumed in the conclusion of this assessment.

5. Fire safety measures

The fire safety measures required as part of the alternative solution are:

5.1 General

1. The existing building is understood to comply with the applicable building standards at the time of construction. All new works associated with the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower will comply with the current DTS provisions of the BCA unless specifically mentioned. This section does not provide a comprehensive list of fire safety measures. The fire safety measures listed within this section relate only to the alternative solutions. The fire safety measures must be read in conjunction with the applicable building standards at the time of construction and/or the DTS provisions of the BCA.
2. The design must comply with the requirements of the fire engineering report for the Western Distributor underpass – report no. SY130111 WD Underpass FER1.1 dated 4 December 2013 prepared by Defire.
3. This report and the requirements listed in this section must be implemented into the design and identified on the fire safety schedule for the building. They must be maintained and certified in accordance with the Environmental Planning and Assessment Regulations 2000 and relevant Australian standards.

5.2 Structural fire resistance

5.2.1 Fire resistance and stability

4. The fire resistance levels (FRLs) of the building elements associated with the all day dining restaurant and associated kitchen on the ground floor must be designed in accordance with the requirements of specification C1.1 of the BCA for type A construction with the exception that the maximum FRL criteria for any element is 120 minutes – eg if an element is required to achieve an FRL of 180/120/90 it can be reduced to 120/120/90. Refer to Figure 3 for relevant areas. Separation of classifications required by clause C2.8 and C2.9 of the BCA is not required in this area.

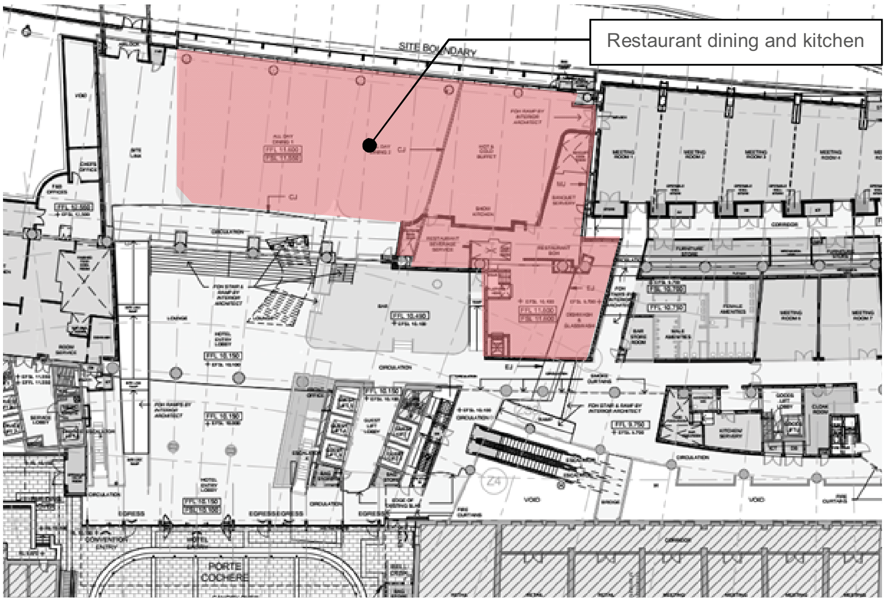


Figure 3 All day dining restaurant and kitchen – reduction in fire rating

5. The ground floor slab above the Western Distributor must achieve an FRL of not less than 240/240/240.

6. The steel roof trusses forming the roof structure of the northern and southern convention rooms on the mezzanine floor need not be fire-rated subject to the following – refer to Figure 4:

   a. Failure of the roof trusses must not result in progressive failure of the remainder of the building structure.

   b. The roof trusses must be lined on the underside by a ceiling constructed of a fire-protective covering as defined by the BCA – this may be in the form of 1 x 13mm fire grade plasterboard

   c. The roof covering must be a non-combustible material

   d. Loadbearing columns, beams and trusses must achieve an FRL of not less than 120/120/120 in accordance with specification C1.1 of the BCA.

7. The Wharf Lane bridge connecting the commercial foyer and Sussex Street may be constructed with a steel structure and timber floor in lieu of achieving an FRL of 120/-/- and 120/120/120 respectively in accordance with specification C1.1 of the BCA for type A construction subject to the following:

   a. A sprinkler system in accordance with the requirements of specification E1.5 of the BCA and AS 21118.1-1999 must be provided within the covered area beneath the bridge.

   b. An alternative path of travel must be provided from the commercial foyer and the discharge location of fire isolated stair 1 and 52 via the Porte Cochere – refer to Figure 5.

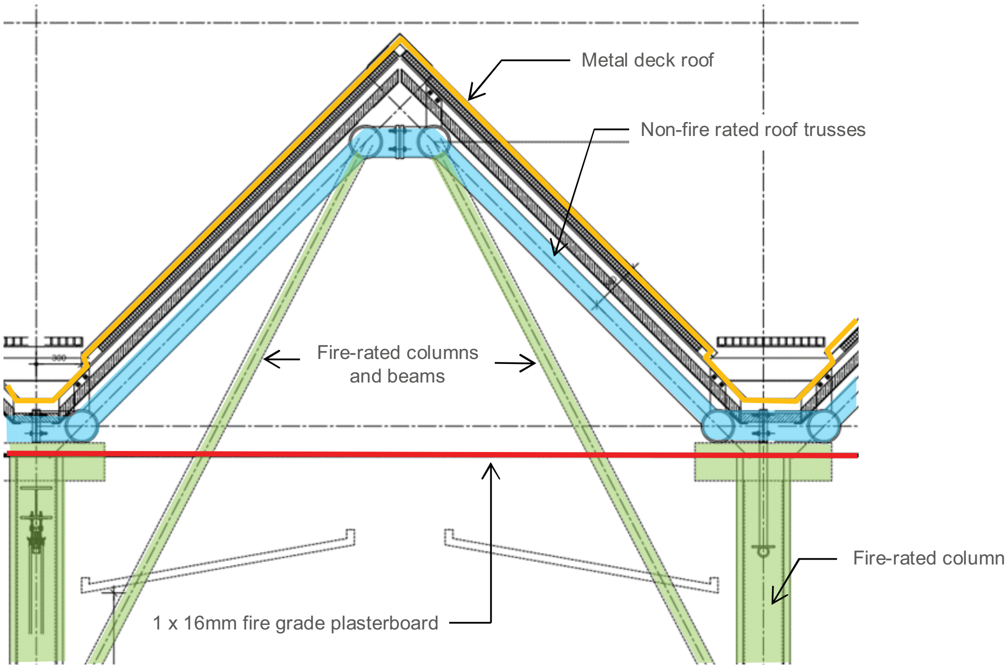


Figure 4 Convention roof structure

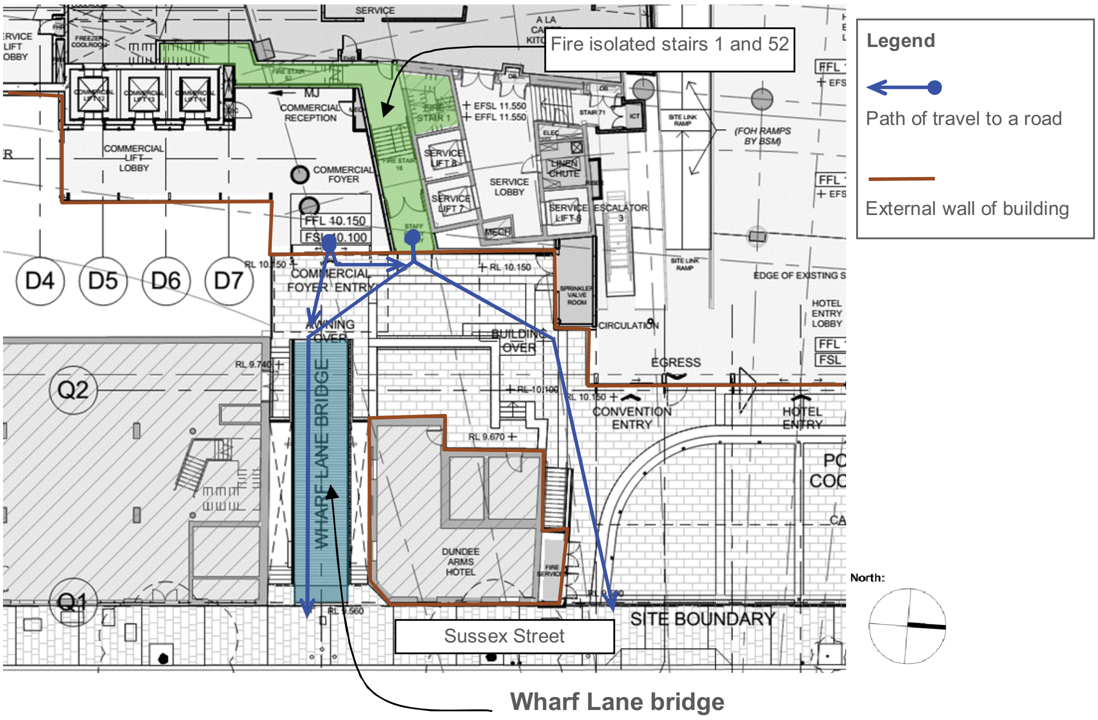


Figure 5 Alternative exits from commercial foyer and fire isolated stairs 1 and 52

5.2.2 Compartmentation and separation

8. The fire compartments identified in Table 7 and detailed in Figure 6 to Figure 9 must be provided to limit fire and smoke spread within the building.

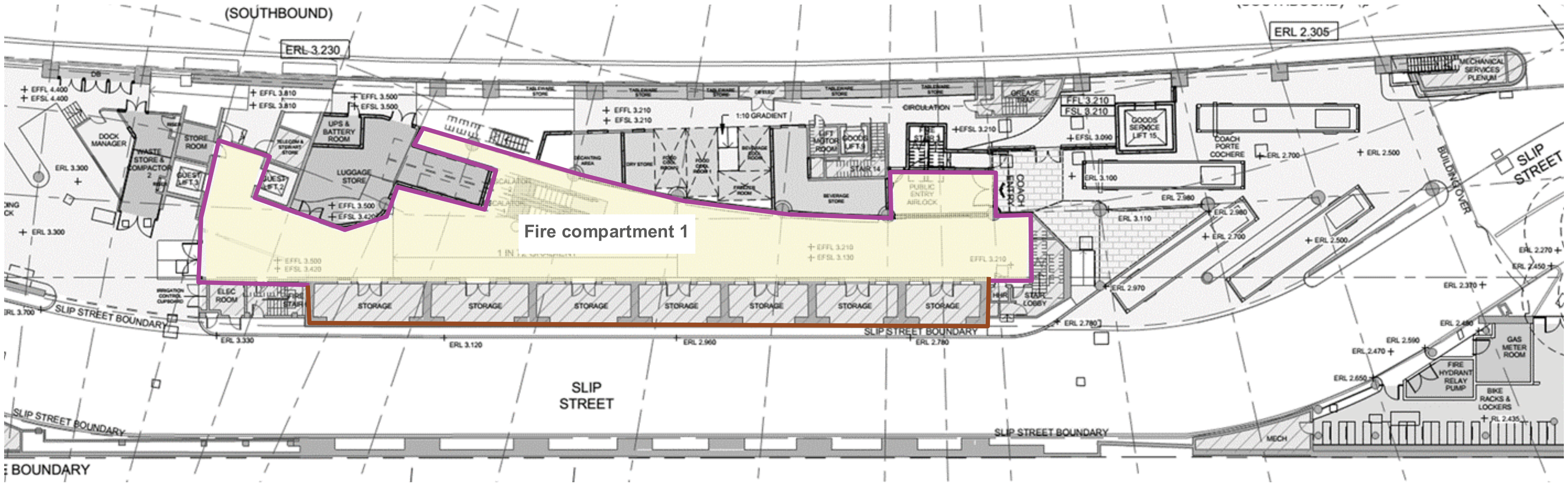
Fire compartment	Levels contained	Approximate floor area
1	Lower ground, ground, mezzanine and level 1	6650m^2
2	Ground and mezzanine	1918m^2
3	Mezzanine and level 1	1835m^2
4	Mezzanine and level 1	1990m^2
5	Ground floor	569m^2
6	Ground floor	1047m^2

Table 7 Fire compartments

Note 1: The fire compartment areas are approximations and not intended to be exact as these may vary once constructed. Fire compartments 2 to 6 must be less than 2000m^2.

Note 2: The eastern portion of the lower ground floor is separated from Slip Street by existing masonry construction. It is understood that mechanical louvers are located within the separating wall at high level which open into a service floor located between the lower ground and ground floors which is substantially separated from the heritage void.

9. Fire walls forming fire compartment boundaries are to be designed in accordance with clause C2.7 of the BCA and shall achieve an FRL of not less than 120/120/120 for loadbearing elements or -/120/120 if non-loadbearing elements. The wall is to extend to the underside of the floor slab above or the underside of a non-combustible roof covering. Refer to Figure 6 to Figure 9 for locations.



Legend

(blue circle)	Self-closing or automatic closing smoke door	(green circle)	Self-closing or automatic closing FRL -/60/30 fire door	(purple circle)	Self-closing or automatic closing FRL -/120/30 fire door	(green box)	Fire isolated exit
(blue line)	Smoke wall	(green line)	FRL 60/60/60	(purple line)	FRL 120/120/120	(brown line)	Existing masonry construction
(blue dotted line)	Smoke curtain with side guides (full height)	(green dotted line)	Fire curtain FRL -/60/- with side guides (full height)	(purple dotted line)	Fire curtain FRL -/120/- with side guides (full height)		

Figure 6 Fire compartmentation – lower ground floor

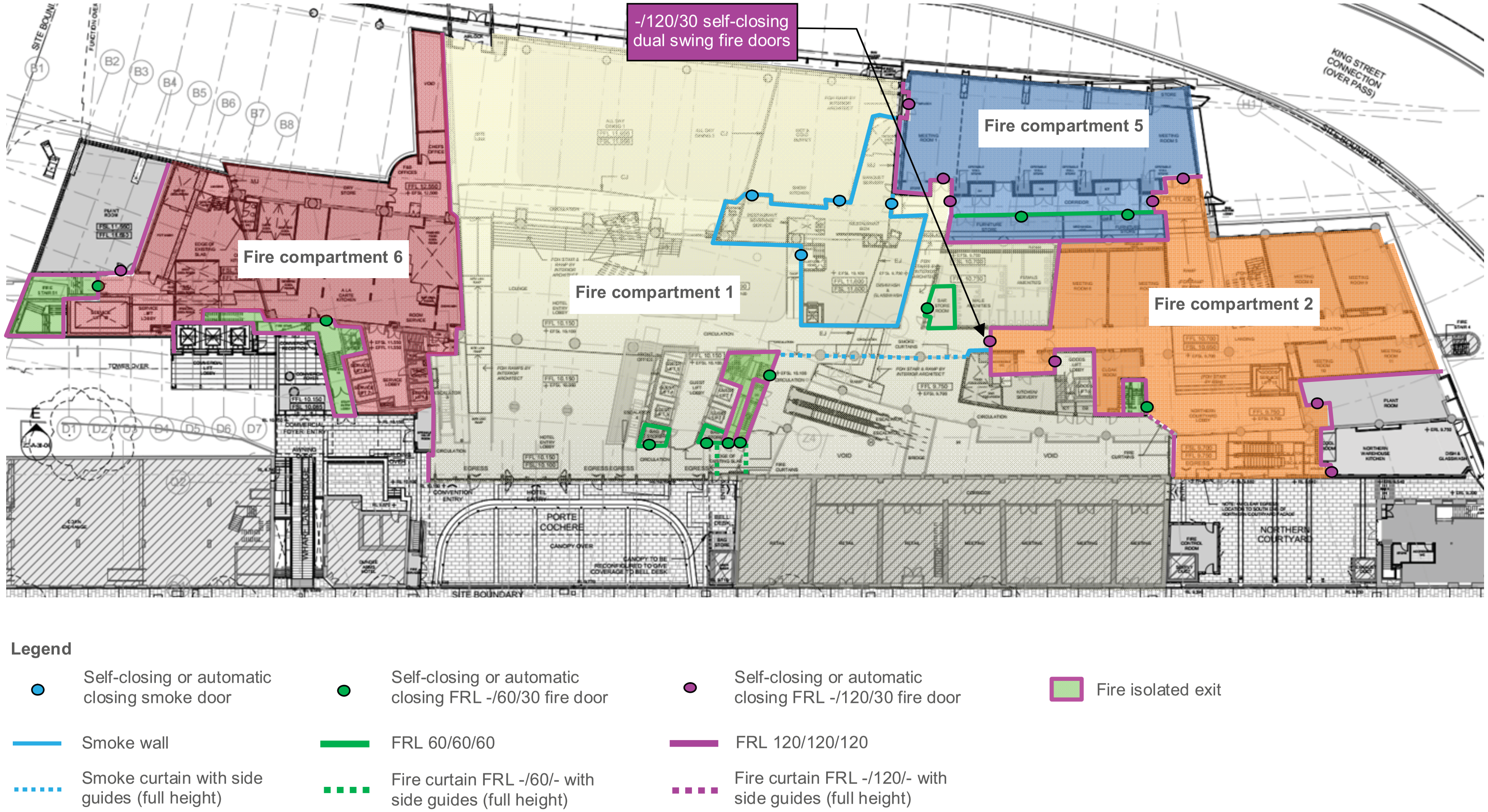


Figure 7 Fire compartmentation – ground floor

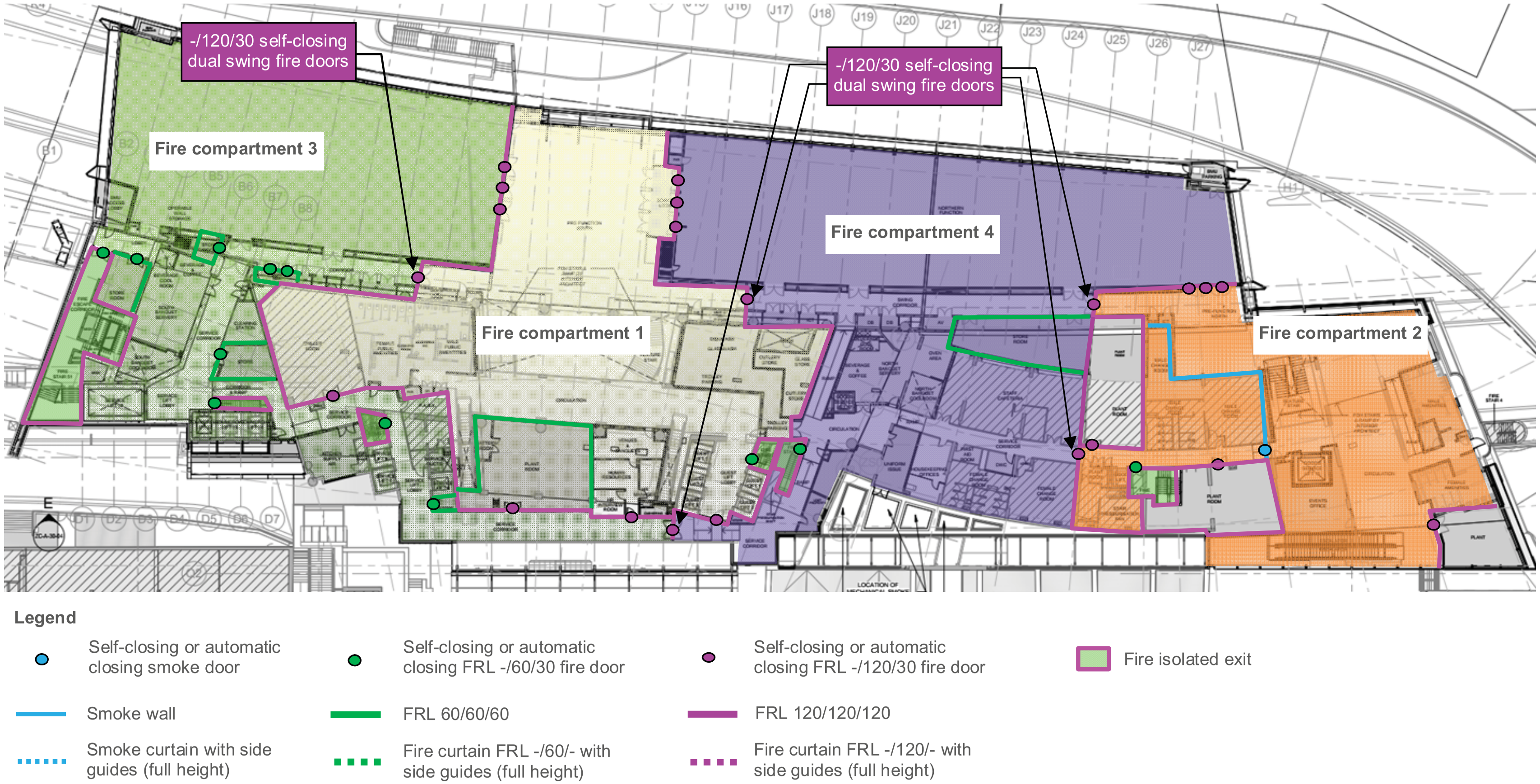
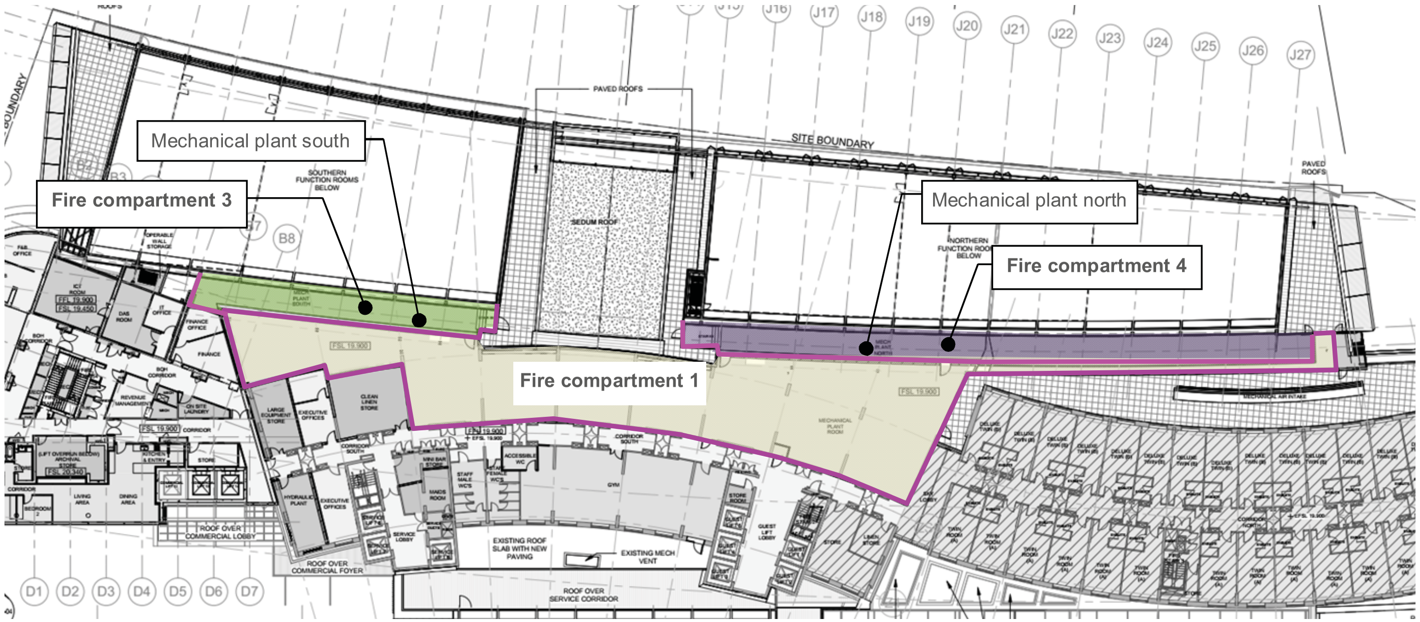


Figure 8 Fire compartmentation – mezzanine floor



Legend

- Self-closing or automatic closing smoke door
- Smoke wall
- Smoke curtain with side guides (full height)
- Self-closing or automatic closing FRL -/60/30 fire door
- FRL 60/60/60
- Fire curtain FRL -/60/- with side guides (full height)
- Self-closing or automatic closing FRL -/120/30 fire door
- FRL 120/120/120
- Fire curtain FRL -/120/- with side guides (full height)
- Fire isolated exit

Figure 9 Fire compartmentation – level 1

10. Any doors in the fire walls must be a self-closing fire door achieving an FRL of -/120/30. Fire doors forming horizontal exits between fire compartments must swing in both directions – refer to Figure 6 to Figure 9 for specific locations. The doors must also be fitted with smoke seals in accordance with clause 3 of specification C3.4 of the BCA and the following requirements:

    a. be medium temperature rated – ie capable of resisting exposure to 200°C for 30 minutes

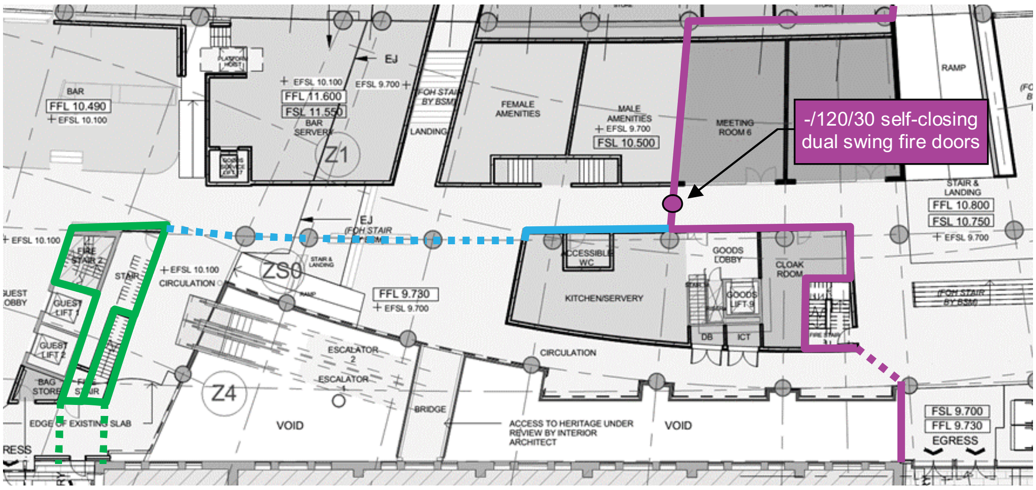
    b. be fitted to all sides of the door including under the door blade.

    We recommend the smoke seals be rebated into the bottom of the doors to improve the reliability of the smoke seals.

11. All storage rooms on the lower ground, ground and mezzanine floors must be enclosed in construction which achieves an FRL of not less than 60/60/60.

12. All plant rooms on the lower ground, ground and mezzanine floors must be enclosed in construction which achieves an FRL of not less than 120/120/120 with the exception of the two mechanical plant rooms serving the southern and northern convention rooms on level 1 as shown in Figure 9. These two plant rooms must not contain any equipment required to be separated under clause C2.12 of the BCA.

13. The heritage void shall be smoke separated from the remainder of the ground floor as identified in Figure 10. The smoke wall indicated in the figure must be a smoke proof wall constructed in accordance with clause 3 of specification C2.5 of the BCA. The wall must not incorporate any glazed areas unless the glass is safety glass as defined in AS 1288-2006.



Legend

●	Self-closing or automatic closing smoke door	●	Self-closing or automatic closing FRL -/60/30 fire door	●	Self-closing or automatic closing FRL -/120/30 fire door
—	Smoke wall	—	FRL 60/60/60	—	FRL 120/120/120
·····	Smoke curtain with side guides (full height)	▪▪▪▪	Fire curtain FRL -/60/- with side guides (full height)	▪▪▪▪	Fire curtain FRL -/120/- with side guides (full height)

Figure 10 Heritage void smoke separation – ground floor

14. Full height vertical fire and smoke curtains shall be provided to separate the heritage void from the remainder of the ground floor as identified in Figure 10. The vertical fire and smoke curtains must comply with the following requirements:

    a. Automatically close upon smoke detector or sprinkler activation within the lower ground or ground floors.

    b. The curtains must incorporate a split drop delay to facilitate occupant evacuation from the heritage atrium side of the curtain. The curtain must drop to a height of 2m above floor level and hold at this position for 30 seconds before completely deploying in the closed position within 60 seconds from receipt of the general fire alarm.

    c. The design of the curtains including side guides must be commensurate with the expected air pressures from the building smoke hazard management systems.

    d. The curtains must be fitted with perimeter smoke seals on both vertical edges of the side guides.

    e. Signs must be installed on each side of the curtains located over the opening or on a wall adjacent to the curtains stating:

    WARNING – AUTOMATIC FIRE / SMOKE CURTAIN

    DO NOT OBSTRUCT

    The words ‘WARNING – AUTOMATIC FIRE CURTAIN’ or ‘WARNING – AUTOMATIC SMOKE CURTAIN’ must be in capital letters not less than 50mm high in a colour contrasting with that of the background and ‘DO NOT OBSTRUCT’ must be in capital letters not less than 20mm high.

    f. Signage and a marked up plan must be clearly displayed at the FIP identifying the locations of the vertical smoke curtains. The signage must be in capital letters not less than 25mm high, in a colour contrasting with that of the background.

    g. Curtains must be tested for 2000 open / close cycles without failure by the manufacturer.

    h. The manufacturer shall ensure that the operating mechanisms and material will maintain satisfactory operation of the smoke curtains during their expected lifetime of not less than 10 years.

    i. Maintenance must be as follows:

        i. Manual deployment via smoke detection and switch at control panel to be undertaken 3-monthly – or more frequently if specified by the manufacturer’s specifications.

        ii. Testing of fail-safe by disconnecting power to control panel must be undertaken 3-monthly – or more frequently if specified by the manufacturer’s specifications.

        iii. Smoke curtains must be listed as a critical essential fire safety measure and maintained 6-monthly by trained and competent technicians – or more frequently if specified by the manufacturer’s specifications.

15. The public corridors of the new hotel tower on levels 1 to 14 must be divided into intervals of not more than 40m with smoke-proof walls as required by clause C2.14 of the BCA. The smoke-proof walls must comply with clause 2 of specification C2.5. Smoke doors provided as part of the separating construction must be fitted with medium temperature smoke seals – ie 200°C. Refer to Figure 13.

5.3 Access and egress

5.3.1 Provision of escape

16. Travel distances within the building must comply with clauses D1.4 and D1.5 of the BCA unless otherwise noted within this report.

17. The following maximum travel distances apply on the southern ground of the building – fire compartment 1 – provided with smoke exhaust. Refer to Figure 11 for worst case area.

    a. 25m to a single exit or point of choice

    b. 60m to the closest of two or more alternative exits

    c. 90m between alternative exits

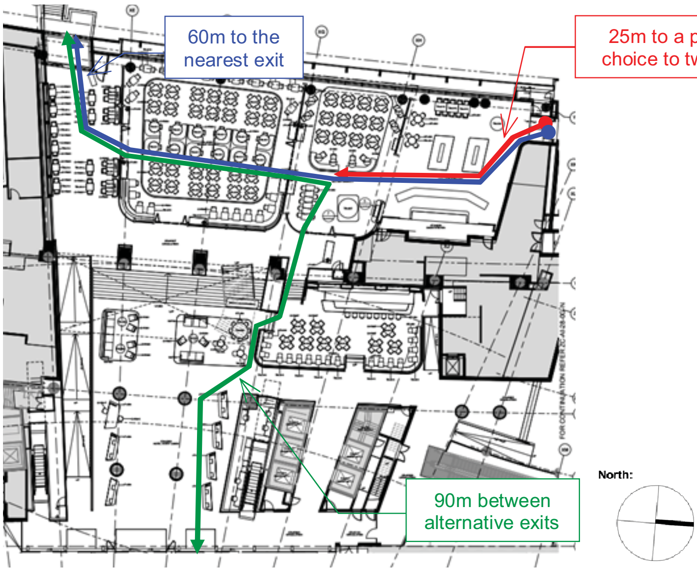


Figure 11 Worst case travel distances on southern ground floor

18. The following maximum travel distances apply on the northern ground of the building – fire compartment 2. Refer to Figure 12 for worst case area.

    a. 30m to a single exit or point of choice

    b. 50m to the closest of two or more alternative exits

    c. 60m between alternative exits

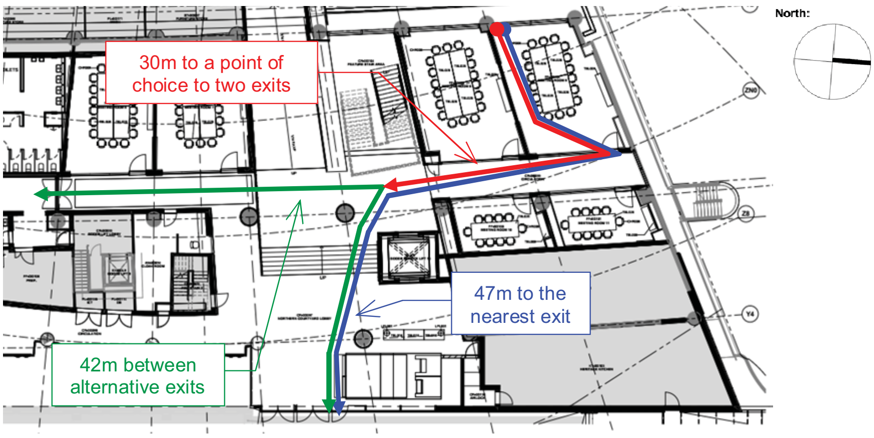


Figure 12 Worst case travel distances on northern ground floor

19. The sole-occupancy units in the class 3 hotel portions of the new hotel tower on levels 1 to 14 have extended travel distances. The relevant sole-occupancy units are identified in Figure 13. The following maximum travel distances apply in these areas.

    a. 8m to an exit or a point of choice from which travel in different directions to two exits is available from the entrance doorway of a sole-occupancy unit.

    b. 20m to an exit or a point of choice from which travel in different directions to two exits is available from any point on the floor of a room which is not in a sole-occupancy unit.

    c. 45m between alternative exits

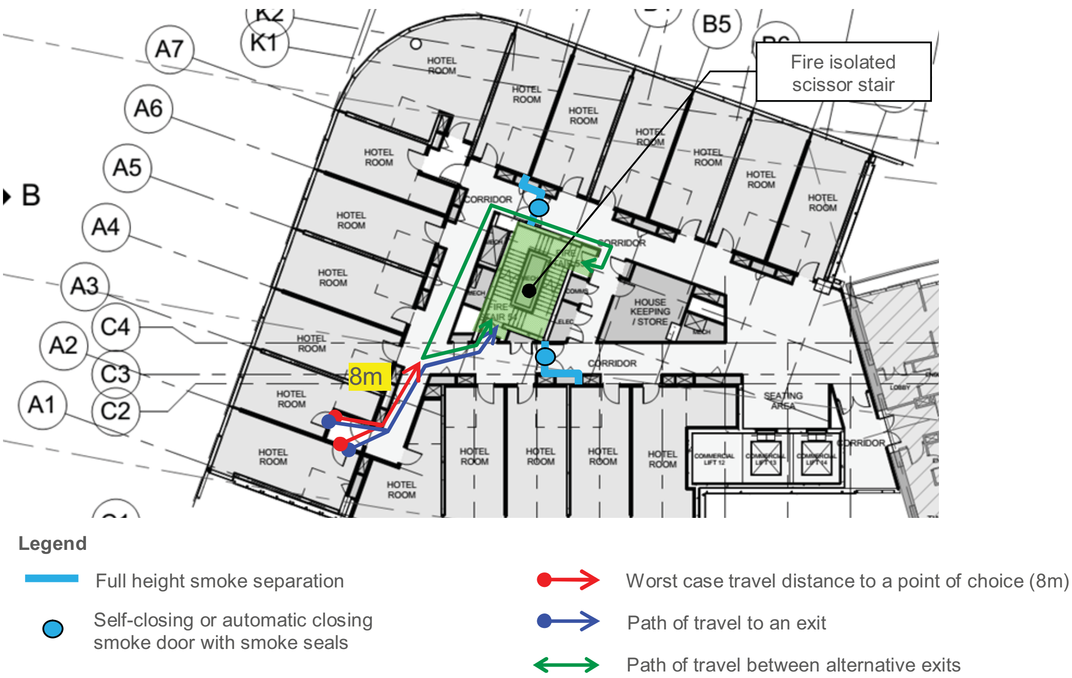
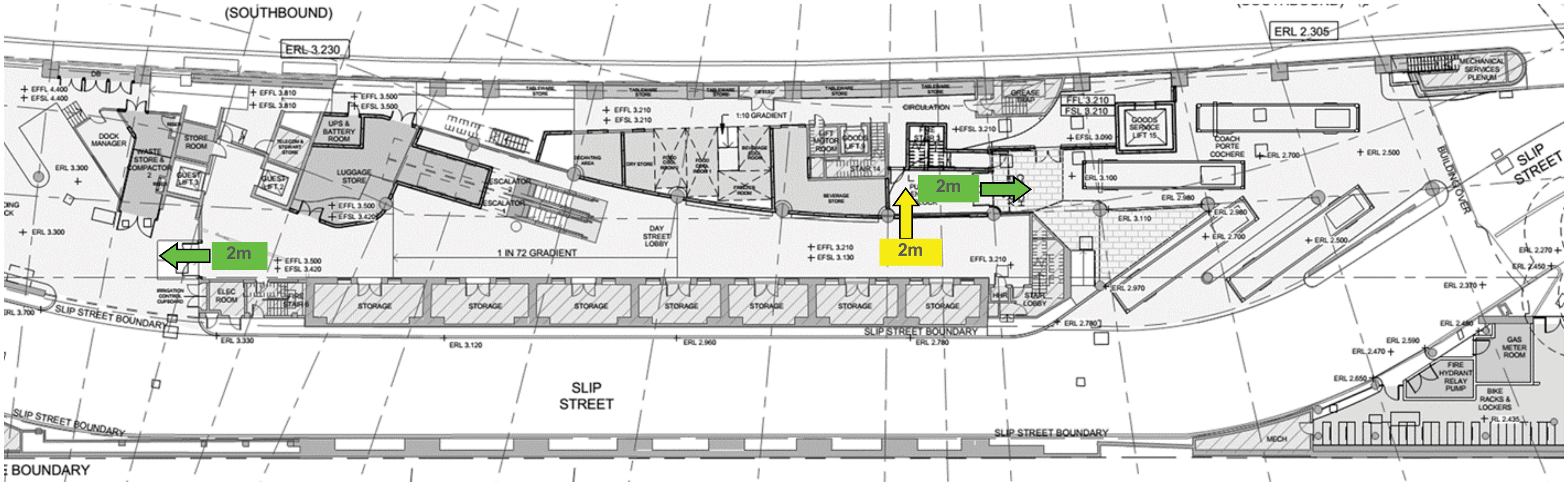


Figure 13 Levels 2 to 15 typical – tower

20. All exits and paths of travel to exits must be not less than 1m in clear width in accordance with clause D1.6 of the BCA.

21. Exits must be provided from the building as identified in Figure 14, Figure 15 and Figure 16. Each exit and path of travel to an exit must have a clear width of not less than the width shown.

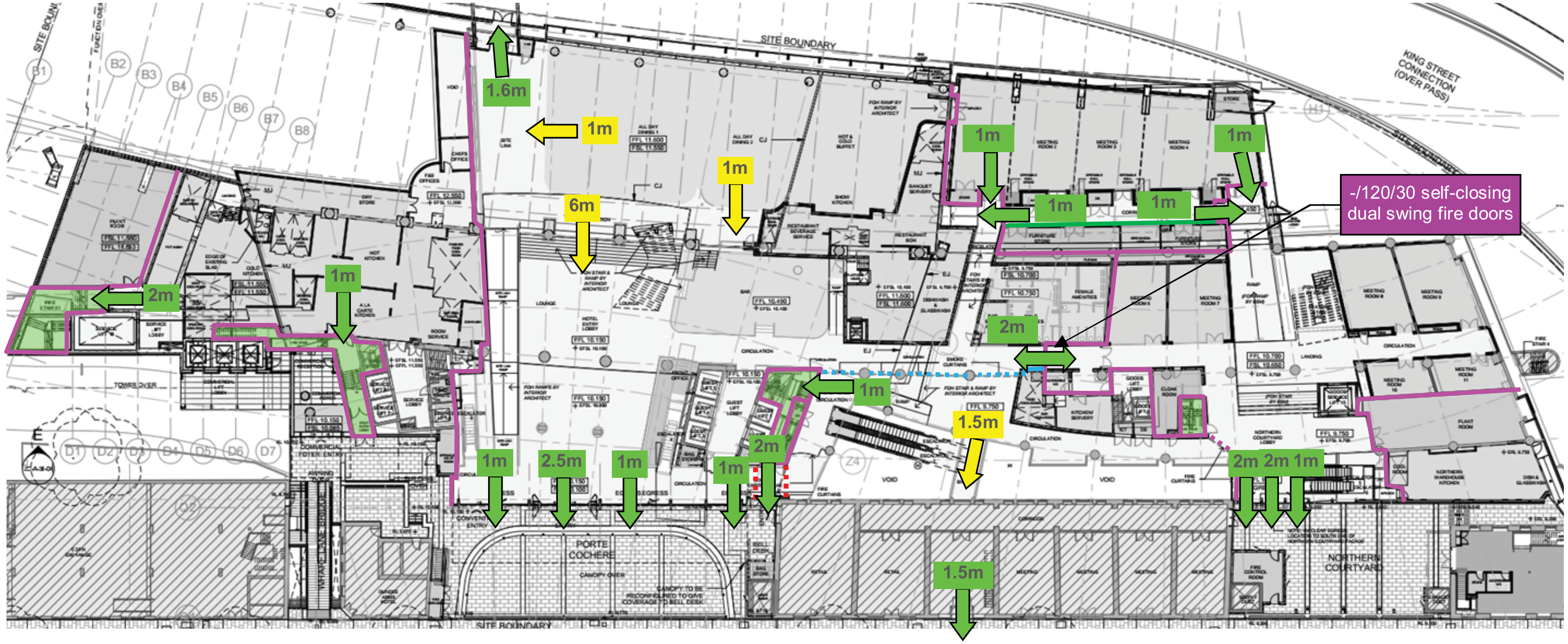


Legend

Path of travel to an exit

Exit

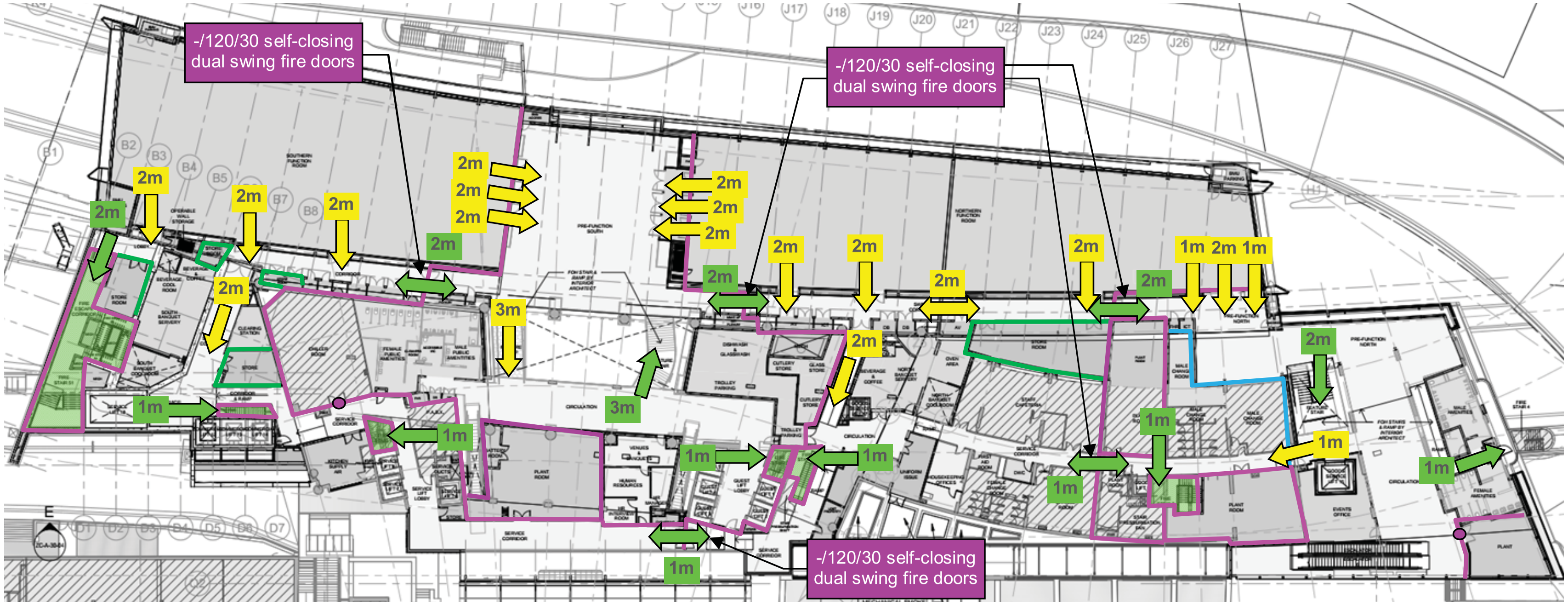
Figure 14 Lower ground floor exits



Legend

- Blue dot: Self-closing or automatic closing FRL -/60/30 fire door
- Green dot: Self-closing or automatic closing FRL -/60/30 fire door
- Purple dot: Self-closing or automatic closing FRL -/120/30 fire door
- Green box with purple outline: Fire isolated exit
- Solid blue line: Smoke wall
- Solid green line: FRL 60/60/60
- Solid purple line: FRL 120/120/120
- Yellow arrow: Path of travel to an exit
- Dotted blue line: Smoke curtain with side guides (full height)
- Dotted green line: Fire curtain FRL -/60/- with side guides (full height)
- Dotted purple line: Fire curtain FRL -/120/- with side guides (full height)
- Green arrow: Exit

Figure 15 Ground floor exits



Legend

Self-closing or automatic closing FRL -/60/30 fire door (blue)	Smoke wall
Smoke curtain with side guides (full height)	Self-closing or automatic closing FRL -/60/30 fire door (green)
FRL 60/60/60	Fire curtain FRL -/60/- with side guides (full height)
Self-closing or automatic closing FRL -/120/30 fire door	FRL 120/120/120
Fire curtain FRL -/120/- with side guides (full height)	Fire isolated exit
Path of travel to an exit	Exit

Figure 16 Mezzanine floor exits

5.3.2 Construction of exits

22. All doorways which form part of a required exit within the building must be made to swing in the direction of travel to the fire isolated exit and from the exit to the discharge point from the building in accordance with clause D2.20 of the BCA.

23. Power operated sliding doors that form an exit or in the path of travel to an exit – ie the hotel lobby entries – which lead directly to a road or open space must:

    a. Be able to be opened manually under a force of not more than 110N if there is a malfunction or failure of the power source; and

    b. Open automatically if there is a power failure to the door or on the activation of the fire alarm – ie smoke detector or sprinkler activation.

24. If a path of travel to an exit or open space requires occupants to pass through back of house, storage areas or roadways where there is a risk of objects such as pallets, boxes and vehicles blocking the evacuation route, the path of travel must be clearly delineated by floor markings. We recommend floor markings with the following characteristics as shown in Figure 17. Refer to Figure 18 and Figure 20 for specific locations.

    a. The width of the path of travel marked on the floor must be equal to the required exit width plus 500mm.

    b. Yellow non-slip paint markings comprising diagonal lines spaced at 300mm intervals within a 300mm wide border.

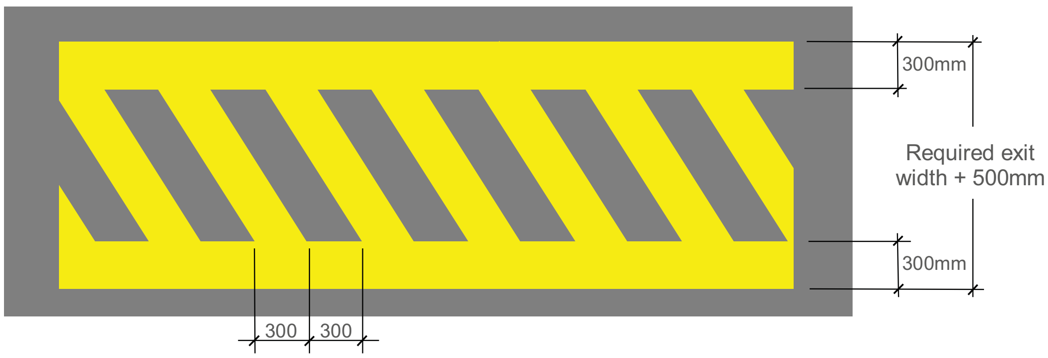


Figure 17 Line marking for paths of travel

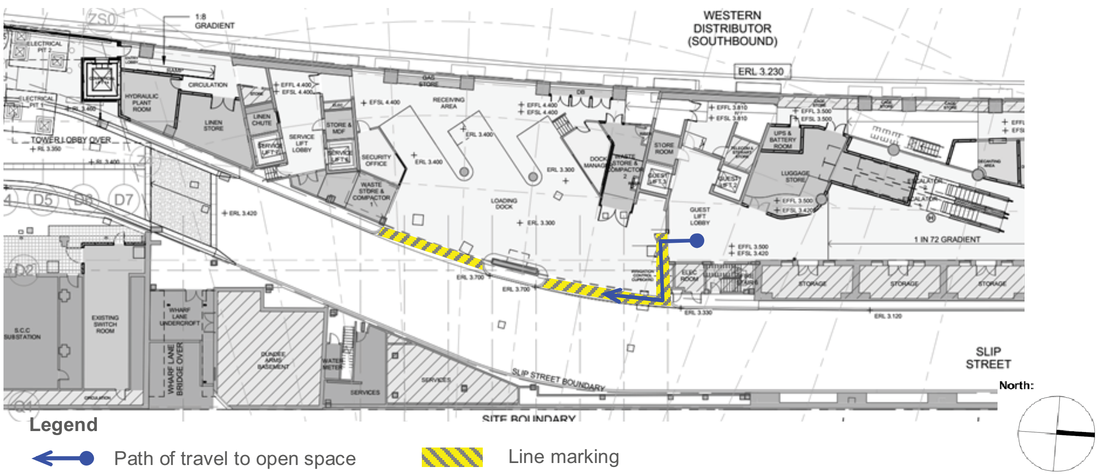


Figure 18 Line marking from the southern exit on the lower ground floor

25. Travel via fire isolated stair 3 must comply with clause D1.7 of the BCA with the exception that it may discharge within the northern lobby of the building on the ground floor – refer to Figure 19. The following additional requirements apply:

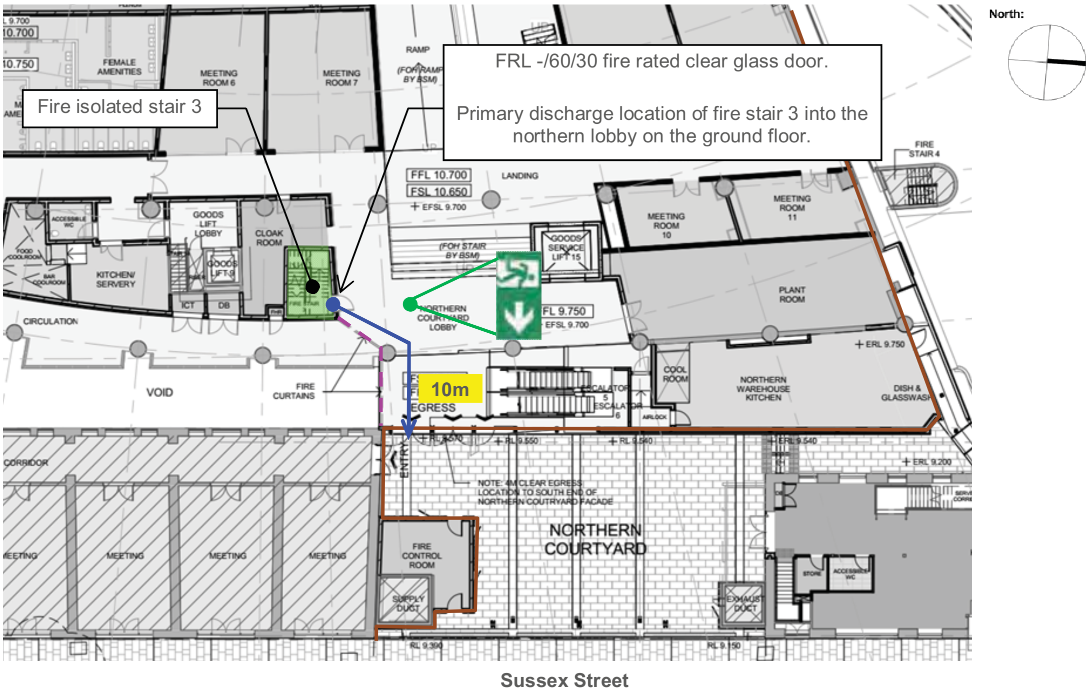
   a. The distance from the point of discharge on the ground floor to the northern exit doors of the building must be not more than 10m.

   b. An alternative discharge location must be provided from the stair on the lower ground floor adjacent to the bus parking bays as shown in Figure 20.

   c. The door opening from the stair into the ground floor must be constructed of clear, fire-rated glazing achieving an FRL of not less than -/60/30. The door must be self-closing and swing in the direction of egress.

   d. A sign must be located inside the stair adjacent to the door discharging into the ground floor. The sign must have an arrow pictorial and capital letters not less than 20mm high, in a colour contrasting with the background as shown in Figure 21.

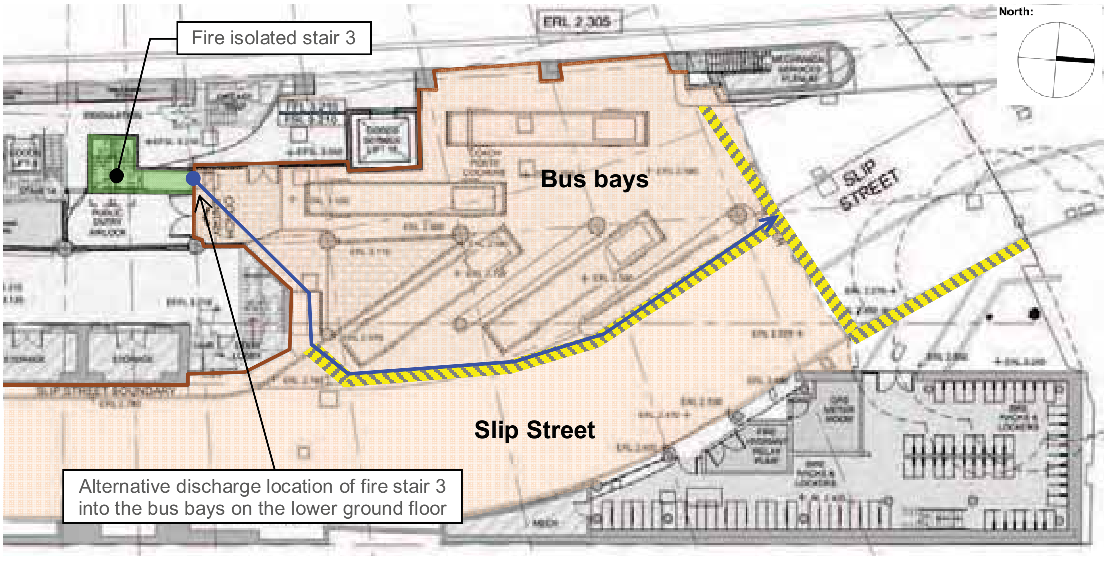
   e. A directional exit sign must be provided in the northern lobby directing occupants discharging from fire stair 3 towards the final exit doors into the northern courtyard as shown in Figure 19. The sign must comply with the requirements of clause E4.8 of the BCA and AS 2293.1-2005.



Legend

Path of travel to an exit — External wall of the building — FRL -/120/- fire curtain

Figure 19 Primary discharge location of fire isolated stair 3 on the ground floor



Legend

Path of travel to open space

External wall of the building

Covered area (floor above)

Line marking

Figure 20 Alternative discharge location of fire isolated stair 3 on the lower ground floor

Figure 21 Directional exit signage inside fire isolated stair 3 on the ground floor

26. Travel via fire isolated stair 2 must comply with clause D1.7 of the BCA with the exception that it may discharge within the main lobby of the building on the ground floor – refer to Figure 22. The following additional requirements apply:

    a. The distance from the point of discharge on the ground floor to the main exit doors of the building must be not more than 4m.

    b. Full height vertical fire curtains achieving an FRL of not less than -/60/- shall be provided to separate the discharge location of fire isolated stair 2 on the ground floor from the remainder of the building. The vertical fire curtains must comply with the requirements identified in item 14a to 14i of section 5 of this report.

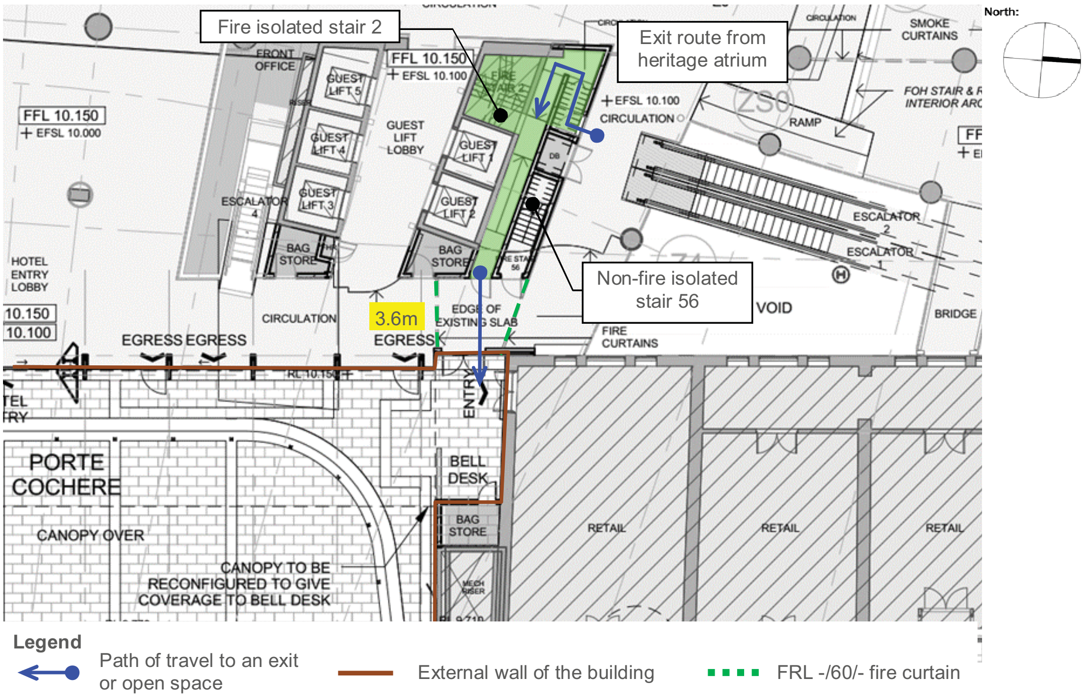


Figure 22 Discharge location of fire isolated stair 2 on the ground floor

27. Fire doors and smoke doors must be provided with a sign in 20mm capital lettering on both sides of the doors. The signs are required to be as follows:

    a. to fire or smoke doors held open with automatic closing hold-open devices:

       FIRE SAFETY DOOR – DO NOT OBSTRUCT

    b. to self-closing fire or smoke doors:

       FIRE SAFETY DOOR
       DO NOT OBSTRUCT
       DO NOT KEEP OPEN

5.4 Services and equipment

5.4.1 Fire fighting equipment

28. A fire hydrant system with a ring main must be installed throughout the building in accordance with the requirements of clause E1.3 of the BCA and AS 2419.1-2005.

    Please note that the fire hydrant booster assembly connections and all fire hydrant valves must be fitted with Storz aluminium alloy delivery couplings manufactured and installed in accordance with clauses 7.1 and 8.5.11.1 of AS 2419.1-2005. Blank caps must be fitted to the couplings via a screw thread. Refer to guide sheet no. 4 'Fire brigade hose couplings' prepared by Fire and Rescue NSW for more information. This document is available at www.fire.nsw.gov.au.

29. A fire hose reel system must be installed throughout the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower in accordance with the requirements of clause E1.4 of the BCA and AS 2441-2005.

30. A sprinkler system in accordance with the requirements of specification E1.5 of the BCA and AS 2118.1-1999 must be provided throughout the lower ground, ground and mezzanine floors of the redeveloped building and the new southern tower. The sprinkler system must have the following additional characteristics:

    a. All sprinkler heads on the lower ground, ground and mezzanine floors must be fast response with an RTI of 50 $(ms)^{1/2}$ or less in accordance with the requirements of AS 2118.1-1999.

    b. Concealed, re-cessed or flush-mounted sprinkler heads must not be used as it may delay sprinkler activation and not achieve fast response activation. Semi-recessed sprinkler heads are considered acceptable provided they achieve a fast response rating.

    c. Activation temperature of 68°C except where otherwise required by AS 2118.1-1999 such as under glazed skylights and roof areas.

    d. Activation of the sprinkler system must operate the smoke hazard management systems of that area and activate the sound system and intercom system as appropriate.

    e. The sprinkler system must be zoned to match the zoning of the smoke exhaust system.

    f. The sprinkler system must be permanently connected with a direct data link or other approved monitoring system to a fire station or fire station dispatch centre in accordance with AS 2118.1-1999.

    g. System component fault monitoring must be provided in accordance with clause 3.4 of AS 2118.1-1999.

    h. Sprinkler valves must be provided to permit zones to be isolated separately. The intent of this requirement is to prevent large areas of a single floor being unprotected at any one time.

    i. Records must be maintained such that there will be no confusion as to which sprinkler head belongs to which sprinkler valve.

    j. Sprinkler booster connections must be provided and located to allow ready access for the fire brigade – ie in close proximity to the fire control room.

    k. The sprinkler system is to be provided with a grade 1 water supply as set-out in AS 2118.1-1999.

31. Where fire hydrants, automatic sprinklers and/or other water based fire safety equipment are connected to a single water supply – either via combined pipework of individual pipework – the minimum water flow requirements must be calculated on the basis that these services will be operating simultaneously.

32. Portable fire extinguishers must be provided as listed in table E1.6 of the BCA and must be selected, located and distributed in accordance with sections 1, 2, 3 and 4 of AS 2444-2001.

33. A fire control room must be provided in accordance with clause E1.8 and specification E1.8 of the BCA. The fire control room is permitted to be accessed from a single path of travel from the front entrance of the building in lieu of two accessible paths as shown in Figure 23.

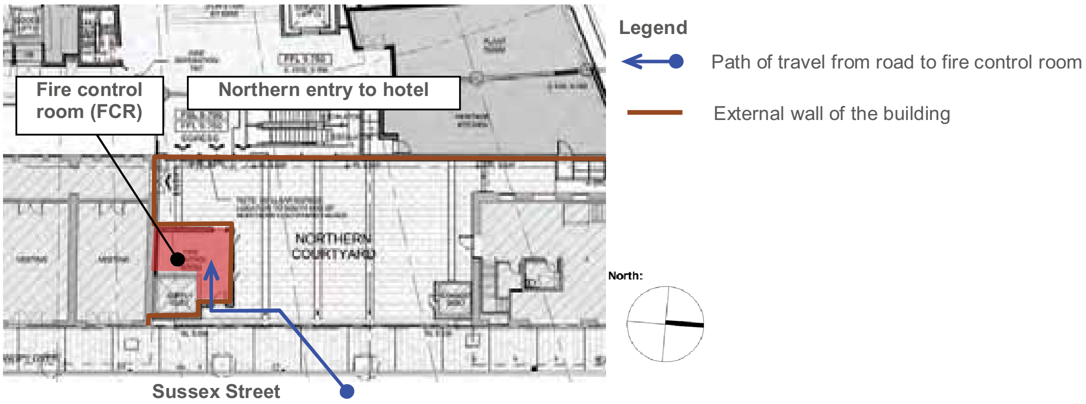


Figure 23 Access to fire control room

5.4.2 Emergency lighting, exit signs and warning systems

34. An emergency lighting system must be installed throughout the lower ground, ground and mezzanine floors of the building and throughout the new southern hotel tower in accordance with clauses E4.2 and E4.4 of the BCA and AS 2293.1-2005.

35. Exit signs and direction signs must be installed throughout the lower ground, ground and mezzanine floors of the building and throughout the new southern hotel tower in accordance with clauses E4.5, E4.6 and E4.8 of the BCA and AS 2293.1-2005.

36. A sound system and intercom system for emergency purposes (SSISEP) in accordance with clause E4.9 of the BCA and AS 1670.4-2004 with pre-recorded verbal evacuation message must be provided. The system must be audible throughout the building.

5.5 Smoke hazard management

5.5.1 Smoke detection and alarm – hotel floors

37. A smoke detection system must be installed throughout the lower ground, ground, mezzanine floors of the redeveloped building and levels 1 to 15 of the new tower in accordance with clause 4 of specification E2.2a of the BCA and AS 1670.1-2004. The following additional requirements apply:

    a. The concession to omit smoke detectors in public corridors for a class 3 sprinkler protected building given by clause 4(c)(ii) of specification E2.2 of the BCA does not apply due to the alternative solution relating to extended travel distance from a sole-occupancy unit.

    b. Activation of the smoke detection system must initiate automatic shutdown of air-handling systems and activation of the SSISEP and smoke exhaust systems.

5.5.2 Activation of smoke control systems

38. Smoke detectors required to activate air pressurisation systems for fire isolated exits, zone smoke control systems and smoke control systems must comply with clause 5 of specification E2.2a of the BCA.

39. All air-handling systems capable of recycling air between the fire/smoke compartments – including between class 3 sole-occupancy units – must be provided with fire/smoke dampers where the air-handling ducts penetrate any elements separating the fire/smoke compartments served in accordance with clause E2.2 of the BCA. The system must be arranged such that the air-handling system is automatically shut down and the fire/smoke dampers close by smoke detectors complying with clause 4.10 of AS/NZS 1668.1:1998.

5.5.3 Smoke exhaust rates and zones

40. The lower ground, ground and mezzanine floors of the building are to be divided into seven smoke zones as indicated in Figure 25, Figure 26 and Figure 27.

41. The back of house area associated with the all day dining restaurant is to be separated from the remainder of the fire compartment by construction, including openings, penetrations and junctions with other building elements, that prevents the free passage of smoke. Smoke dampers are not required for any duct penetrations or the like. Refer to Figure 24

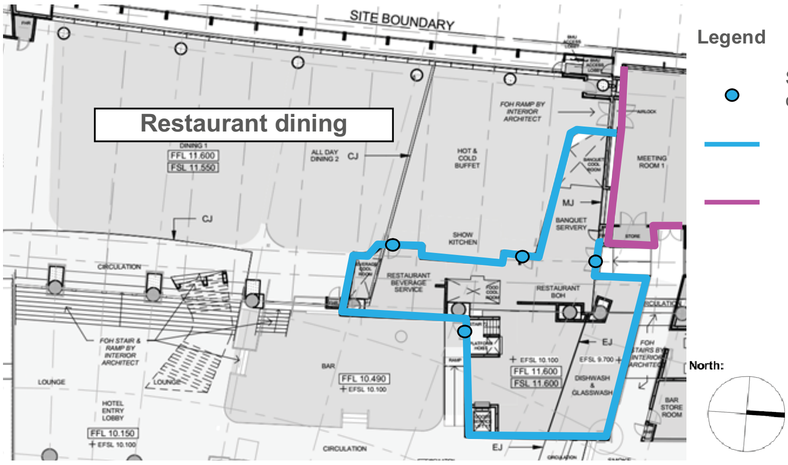


Figure 24 Smoke separation of all day dining back of house areas

42. The lower ground, ground and mezzanine floors of fire compartment 1 within the building must be provided with an automatic smoke exhaust system complying with the requirements of specification E2.2b of the BCA except where specifically addressed by this alternative solution report.

    Note: Smoke exhaust is not provided to the other fire compartments on the lower ground, ground and mezzanine floors as these compartments have a floor area of less than 2000m^2 and are not required to be provided with smoke exhaust under NSW table E2.2b of the BCA.

43. Smoke exhaust need not be provided in the following parts of fire compartment 1:

    a. Ground floor – all day dining, kitchen and back of house areas

    b. Mezzanine floor – dishwash and glass wash, amenities and back of house areas

    Refer to Figure 25, Figure 26 and Figure 27 for locations.

44. Smoke exhaust must be provided within the smoke zones as described in Table 8 and illustrated in Figure 25, Figure 26 and Figure 27. The smoke exhaust must be programmed in accordance with the matrix described in Table 9.

Smoke Zone ID	Smoke zone	Total exhaust rate	Distribution
A	Lower ground floor / ground floor heritage void	25m^3/s	2 x 12.5m^3/s
C	Ground floor south	51m^3/s	3 x 7m^3/s (ground floor south lobby) 3 x 10m^3/s (mezzanine south)

Table 8 Smoke exhaust rates for smoke zones

45. Each smoke exhaust fan, complete with its drive, flexible connections, control gear and wiring must:

    a. be constructed and installed so that it is capable of continuous operation – exhausting the required volumetric flow rate at the installed system resistance – at a temperature of 200°C for a period of not less than 1 hour,

    b. be rated to handle the required volumetric flow rate at ambient temperature to be capable of exhausting cool smoke during the early stages of a fire and to allow routine testing, and

    c. have any high temperature overload devices installed, automatically overridden during the smoke exhaust operation.

46. Each smoke exhaust fan must be activated sequentially by smoke detectors complying with specification E2.2a of the BCA and arranged in zones to match the smoke reservoir served by the fan(s).

    a. Subject to item b, an air handling system – other than individual room units less than 1000l/s and miscellaneous exhaust air systems installed in accordance with sections 5 and 11 of AS/NZS 1668.1:1998 – which does not form part of the smoke hazard management system must be automatically shut down on the activation of the smoke exhaust system.

    b. Within a multi-storey fire compartment, air handling systems in all non fire-affected zones and storeys must operate at 100% outdoor air to provide make-up air to the fire-affected storey via building voids connecting storeys.

    c. Manual override control and indication together with operating instructions for use by emergency personnel must be provided adjacent to the fire indicator panel in accordance with the requirements of clauses 4.13 and 4.15 of AS/NZS 1668.1:1998.

    d. Power supply wiring to exhaust fans together with detection, control, and indication circuits – and where necessary to automatic make-up air supply arrangements – must comply with AS/NZS 1668.1:1998.

5.5.4 Make-up air for smoke exhaust

47. The make-up air required for the smoke exhaust systems are proposed to be provided via a combination of passive openings and mechanical make-up air as shown in Figure 25, Figure 26 and Figure 27.

48. The openings required for passive and mechanical make-up air must comply with the following requirements:

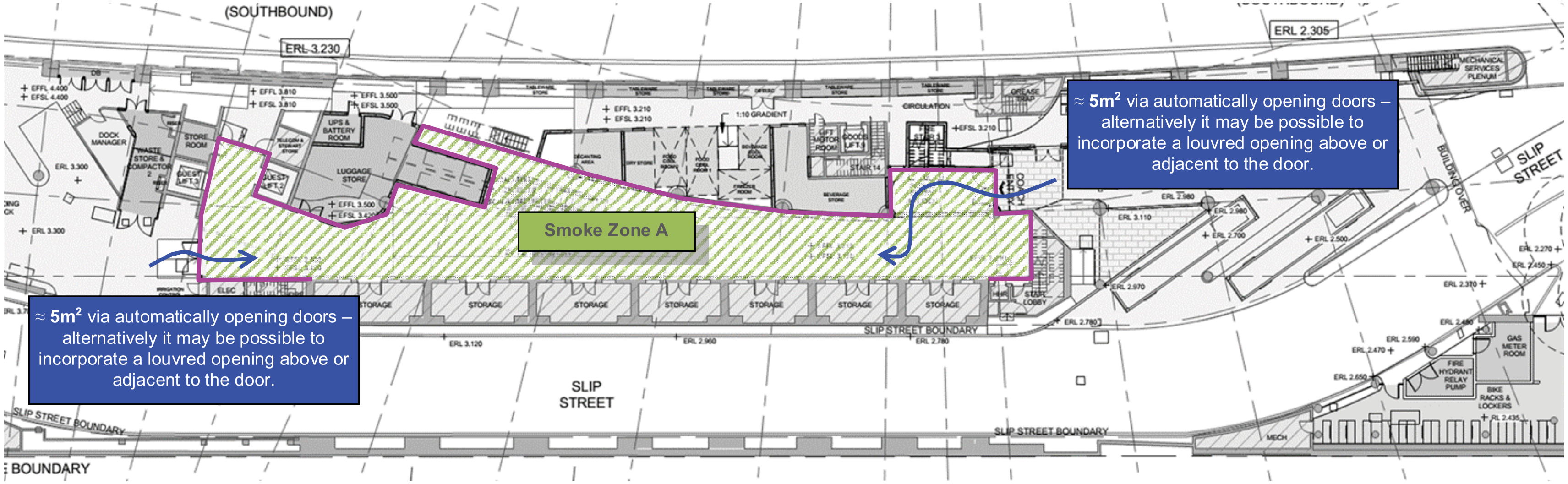
    a. The velocity of make-up air through doorways and/or louvres must not exceed 2.5m/s.

    b. Open automatically upon activation of the smoke hazard management system on the lower ground, ground or mezzanine floor in accordance with Table 9.

    c. Operable doors for smoke control make-up air must fail-safe in open position or be provided with a dedicated battery backup that can fully open the doors in the event of a power failure.

5.5.5 Automatic stair pressurisation

49. Fire isolated stairs, passages and lobbies must be provided with a stair pressurisation system in accordance with table E2.2a and AS/NZS 1668.1:1998.



Legend

Self-closing or automatic closing FRL -/60/30 fire door	Self-closing or automatic closing FRL -/60/30 fire door	Self-closing or automatic closing FRL -/120/30 fire door
Smoke wall	FRL 60/60/60	FRL 120/120/120
Smoke curtain with side guides (full height)	Fire curtain FRL -/60/- with side guides (full height)	Fire curtain FRL -/120/- with side guides (full height)

Fire isolated exit

Figure 25 Smoke hazard management requirements – lower ground floor

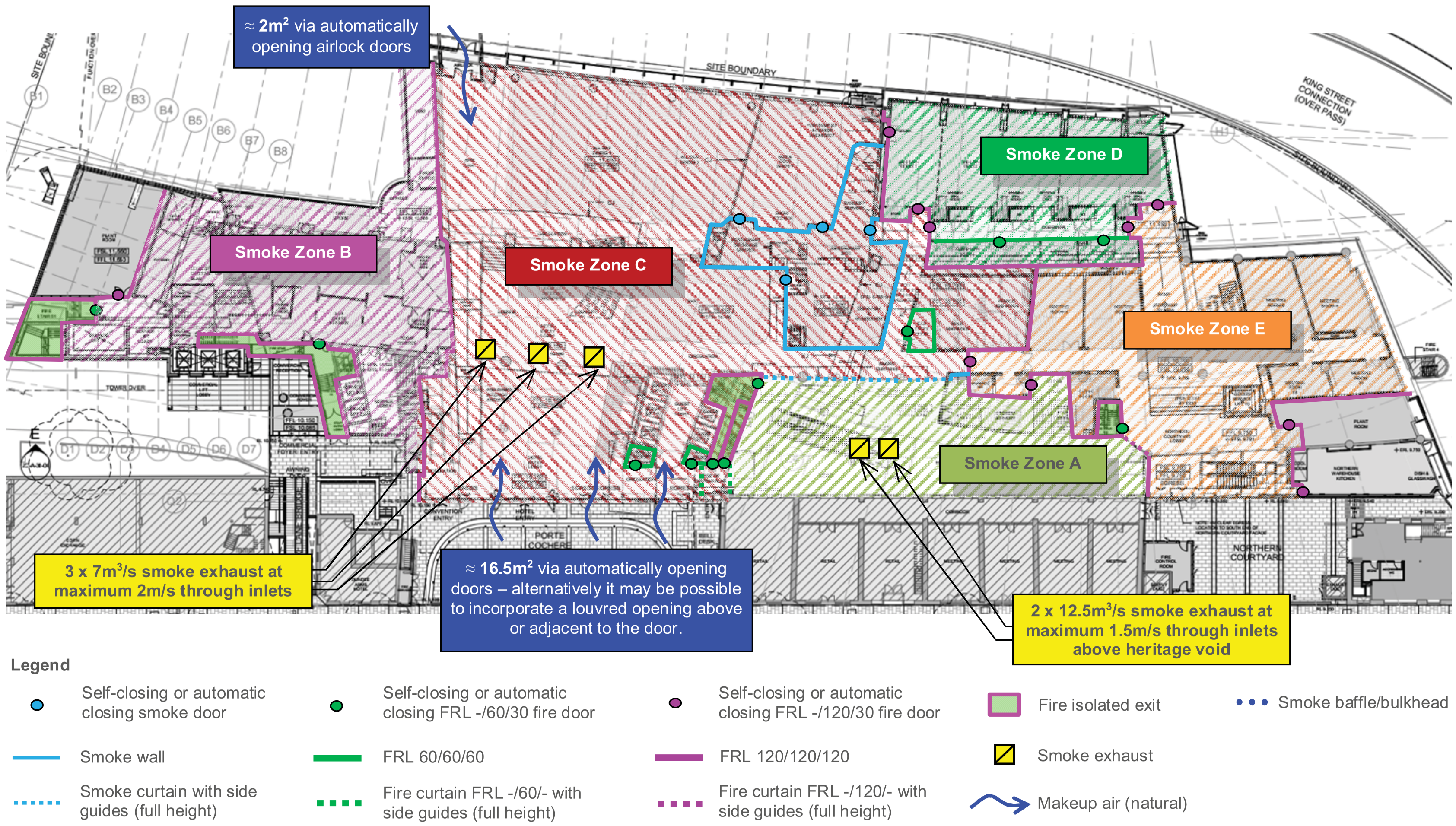


Figure 26 Smoke hazard management requirements – ground floor

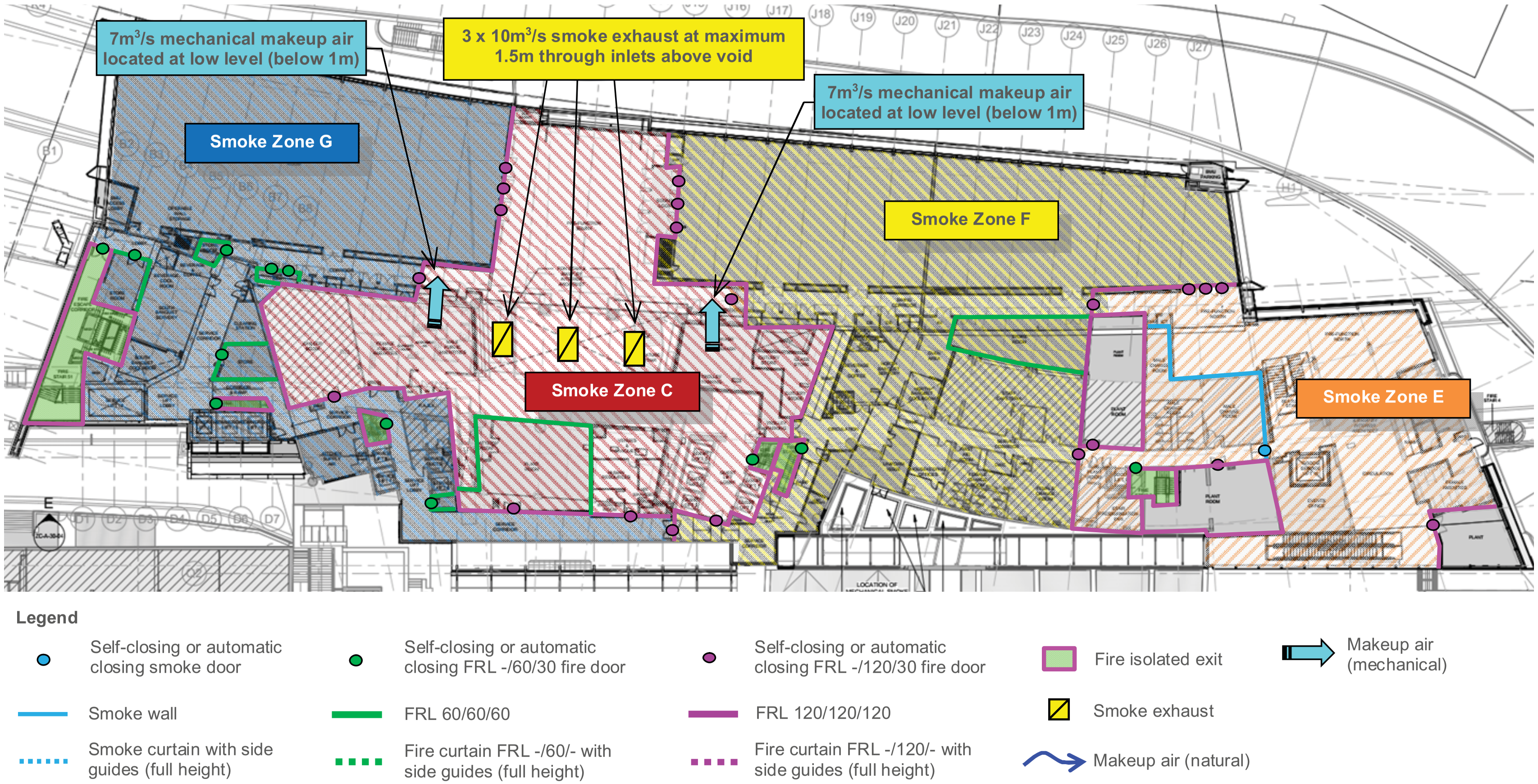


Figure 27 **Smoke hazard management requirements – mezzanine floor**

Smoke Zone ID	Zone Description	Smoke exhaust			Mechanical makeup air	Automatic Doors				Curtains
		Heritage void 2 x $12.5m^3/s$	Ground floor south lobby 3 x $7m^3/s$	Mezzanine south above main void 3 x $10m^3/s$	Mezzanine south 2 x $7m^3/s$	Automatic opening doors – lower ground floor	Automatic opening doors – ground floor	Automatic closing fire doors – ground floor	Automatic closing fire doors – mezzanine floor	Fire and smoke curtains drop – ground floor
A	Lower ground floor / ground floor heritage void	X			X	X	X			X
B	Ground floor south					X	X			
C	Ground/mezzanine floor main lobby		X	X	X	X	X	X	X	X
D	Ground floor northwest meeting rooms					X	X	X		
E	Ground/mezzanine floor north					X	X	X	X	X
F	Mezzanine floor north convention					X	X		X	
G	Mezzanine floor south convention					X	X		X	

Table 9 Smoke hazard management matrix

Note: Some doors in other compartments open due to exit requirements.

5.6 Fire safety management and training

50. An emergency management plan complying with AS 3745-2010 must be developed and implemented for the building within three weeks of occupation.

    Once the emergency management plan is developed, it is to be implemented with exercises, periodic audits, and suitable procedures to maintain safety. This should include training under simulated fire emergency conditions for all relevant personnel.

51. A fire safety management plan (FSMP) must be developed for the building. A FSMP is an overview of the fire safety systems installed throughout the building, with additional information relating to maintenance, housekeeping and procedures. This document must include the following information as a minimum:

    a. Identification of the building owner / manager responsible for implementation of the FSMP.

    b. A set of drawings showing the following fire safety measures for ease of maintenance and reference:

       - fire / smoke compartmentation
       - location and width of exits and paths of travel
       - fire hydrants and fire hose reels
       - warden intercom phones
       - fire indicator panel (FIP), fire fan control panel (FFCP) and mimic panels etc
       - smoke hazard management provisions including location of exhaust and make-up air
       - fire-fighting services including the booster assembly, fire pump rooms and fire control room
       - sprinkler, smoke hazard management and emergency warning zones
       - any other unique or non-standard fire safety measures required as part of the alternative solution report, eg smoke curtains

    c. Maintenance requirements for the fire safety measures in the building in accordance with the relevant Australian standards and applicable legislation.

    d. Identification of any alternative solutions and associated fire safety measures.

    e. Identify the requirement for an emergency evacuation plan to be developed, implemented and maintained for the building in accordance with AS 3745-2010.

    f. General housekeeping procedures to minimise the fire risks within the building.

    g. A population management plan is to be developed for the premises. The plan is to detail maximum populations for specific areas, how populations will be controlled, any additional requirements for 'special events', and the frequency and duration for utilisation of each specific area. The population management plan is to take into consideration the evacuation requirements included in this document and any associated procedures for evacuation must be included in the emergency management plan.

    h. Fire risk management procedures for maintenance and building works, including:

       - Isolation of any of the fire safety measures for the building should be the subject of a risk assessment and approval process controlled by the owners / management.
       - Maintenance works requiring shutdown or isolation of the sprinkler system should be undertaken outside of normal trading hours when possible.
       - If the sprinkler system is isolated or turned off for an extended period – eg more than two days – the relevant area must be temporarily fire separated from the

remainder of the building by fire-rated construction. A risk assessment should be undertaken to determine the appropriate fire rating.

- Procedures for all 'hot work' such as welding, oxyacetylene cutting, paint stripping, vinyl laying etc. Where conducted outside the confines of a dedicated workshop, these works should be the subject of a hot works approval process controlled by the building owner / manager.

i. The FSMP is to be reviewed on an annual basis or whenever alteration and additions, changes in use, population or fire safety measures occur.

5.7 Commissioning of fire safety strategy

52. The building work and fire safety measures relating to the alternative solution report must be inspected by an appropriately qualified fire safety engineer prior to occupation to confirm that the holistic performance is consistent with these requirements. Detailed inspections and commissioning tests for the building fire safety systems will need to be undertaken separately by the relevant consultants and/or installers.

Table 10 sets out what will be required as a minimum to confirm that the building is consistent with the recommendations of the alternative solution report.

Fire safety measures	Certification from relevant consultant / installer	Visual spot checks by fire safety engineer / interview installer	Holistic witness testing by fire safety engineer
Fire rating of structural elements	✓	✓	
Fire and/or smoke doors	✓	✓	✓
Exits and paths of travel	✓	✓	
Emergency lighting and exit signage	✓	✓	
Portable fire extinguishers	✓	✓	
Smoke detection system	✓	✓	✓
Sound system and intercommunication system for emergency purposes	✓		✓
Sprinkler system	✓	✓	✓
Fire hydrant system	✓	✓	✓
Fire hose reel system	✓	✓	
Smoke exhaust system and makeup air	✓	✓	✓
Stair pressurisation	✓		✓
Emergency management plan and fire safety management plan	✓		

Notes:

- Operation of smoke detectors will need to be simulated using smoke aerosol spray.
- Operation of sprinkler system will need to be demonstrated by opening test valve.
- Operation of smoke control / occupant warning systems will need to be witnessed following activation of smoke detection / sprinkler system, including holistic check of general air movements for design scenarios.
- Operation of automatic fail safe devices / automatic fire and smoke doors/ automatic fire/smoke curtains to be confirmed following activation of smoke detection / sprinkler system.
- Hydrant valve to be opened to confirm that the system is charged.

Table 10 Required certificates and testing

6. Alternative solution 1 – Smoke hazard management and evacuation on podium levels

6.1 Introduction

The lower ground, ground and mezzanine podium levels of the hotel comprise primarily class 9b hotel, meeting rooms and convention rooms and a class 6 restaurant. The podium levels will be divided into six fire compartments as indicated in section 5.2.2. All six fire compartments – with the exception of fire compartment 1 – have a floor area of less than 2000m^2. NSW table E2.2b of the BCA does not require smoke exhaust to be provided in fire compartments with a floor area of less than 2000m^2.

It is proposed to provide automatic smoke exhaust in the main, southern fire compartment of the hotel – fire compartment 1 – which is approximately 6650m^2. The smoke exhaust system will be provided within the circulation areas of the class 9b portions within the heritage void, the main hotel lobby on the ground floor, the southern mezzanine pre-function. No smoke exhaust is proposed to be provided within the class 6 restaurant which is within the same fire compartment.

The smoke exhaust rates and smoke reservoir configurations are proposed to be designed on a performance basis as described in section 5.5 in lieu of achieving full compliance with specification E2.2b of the BCA.

Fire compartment 1 will be divided into two smoke hazard management / sprinkler zones as indicated in Figure 25, Figure 26 and Figure 27 of section 5.5.3. This comprises:

- Heritage void on the lower ground and ground floor
- Main hotel lobby on the ground floor and southern pre-function on the mezzanine floor

The southern portion of the ground floor also includes travel distances in excess of the requirements of clauses D1.4 and D1.5 of the BCA. The proposed design incorporates the following maximum travel distances:

- Travel distance to a point of choice up to a maximum of 25m in lieu of 20m.
- Travel distance up to a maximum of 60m in lieu of 40m.
- Distance between alternative exits up to a maximum of 90m in lieu of 60m.

This assessment was undertaken to demonstrate that the design complies with performance requirements DP4 and EP2.2 of the BCA.

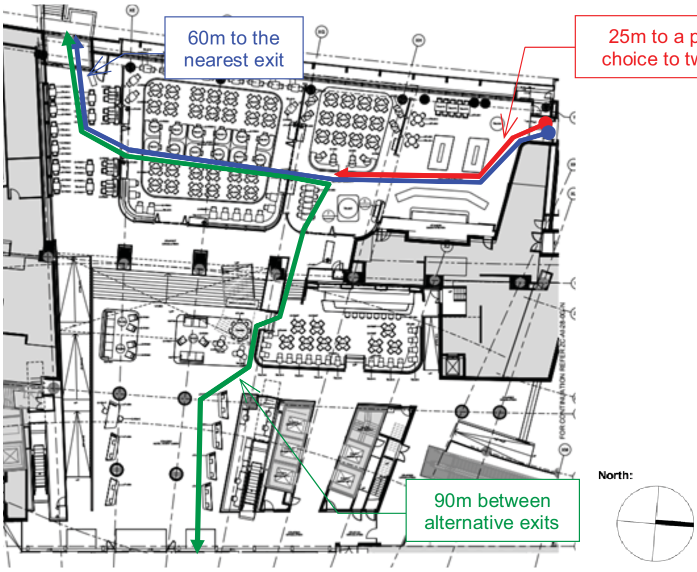


Figure 28 Travel distances on southern ground floor

6.2 Intent of the BCA

6.2.1 Travel distances – clauses D1.4 and D1.5

The Guide to the BCA states that the intent of clause D1.4 is 'to maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate.' The guide explains that 'the clause D1.4 travel distances are based on an assumption of what is considered 'reasonable' distances to be travelled by occupants in reaching an exit.'

The guide elaborates on the intent of the travel distance to a single exit or point of choice requirement where people are assumed to be alert and awake. 'Clause D1.4(c)(i) sets out the maximum travel distance in class 5-9 buildings. The distances specified allow people to evacuate in a reasonable time, assuming that they are not asleep. In case a fire blocks a path of travel, clause D1.4(c)(i) requires that alternative routes must be available within 20m of the starting point, unless it is possible to reach a single exit within 20m.'

The Guide to the BCA says that the intent of clause D1.5 is 'to require that if an exit is inaccessible, access to any required alternative exit must be available within a reasonable distance.' The guide explains that 'where a building requires multiple exits, the exits maximise the choices of a person evacuating, in case one exit becomes blocked.'

The guide elaborates on the intent of the maximum travel distance between alternative exits requirement – 'the maximum distance between alternative exits minimises the need to travel too far to reach an exit.'

6.2.2 Smoke hazard management – clause E2.2

The Guide to the BCA states that the intent of clause E2.2 of the BCA is 'to specify the requirements for minimising the smoke risks'. The guide explains that the intent of specification E2.2b – in part – is 'to specify the capacity and exhaust rates required of mechanical smoke exhaust systems' and 'to specify the requirements for smoke reservoirs, to enable the containment of smoke in the upper levels of compartments.'

6.3 Methodology

The assessment undertaken for the building was a quantitative absolute analysis supported by qualitative assessment involving the following sub-systems:

- Sub-system A – Fire initiation and development and control
- Sub-system B – Smoke development and spread and control
- Sub-system C – Fire spread and impact and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control
- Sub-system F – Fire services intervention

6.4 Acceptance criteria

6.4.1 ASET / RSET timeline

The acceptance criteria for the assessment are that the proposed design of the building facilitates safe occupant egress and fire brigade intervention in the event of a fire.

The available safe evacuation time (ASET) and the required safe evacuation time (RSET) will be compared to demonstrate that an adequate margin can be achieved for the worst-credible fire scenarios. The ASET / RSET timeline is illustrated in Figure 29.

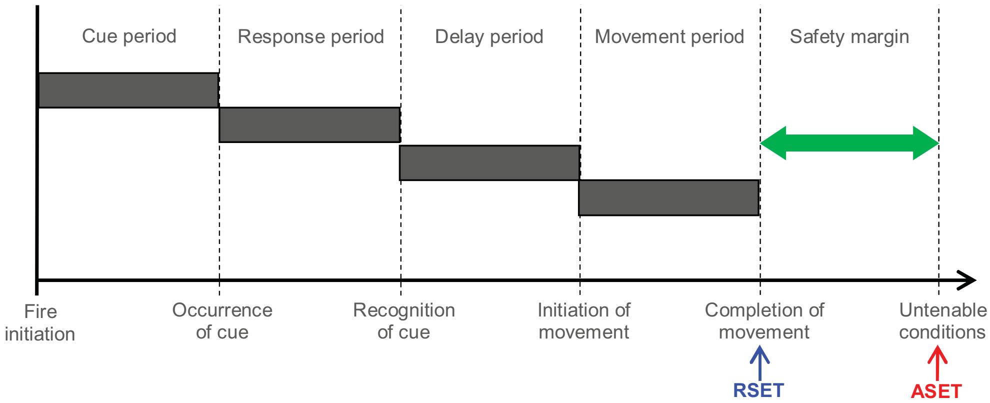


Figure 29 ASET / RSET timeline

6.4.2 Safety factor

All engineering analysis includes a varying degree of uncertainty associated with the assessment methodology and in the estimated input values depending on the amount of relevant statistical data and research available. To account for these potential variations and uncertainties the IFEG recommends that a suitable safety factor be included in the ASET / RSET assessment to achieve an acceptable level of safety.

The required safety factor will depend on the accuracy and level of conservatism of the assessment methodology and the estimated input variables. The greater level of conservatism, the lower safety factor required to achieve the satisfactory level of safety. For worst-credible fire scenarios and conservatively assumed input values no or very limited safety factor is required[9].

For the purpose of this assessment localised or sprinkler controlled fire scenarios will be used for the ASET / RSET analysis with an additional safety factor of 1.5 – ie a margin of safety equivalent to 50% of each of the components of the RSET will be adopted.

Additional safety factors will not be applied when undertaking sensitivity analyses.

6.4.3 Building occupants

Table 11 summarises the criteria used to assess the tenability of evacuation routes. These parameters are evaluated at 2m above finished floor level. This is consistent with specification E2.2b of the BCA which requires smoke control systems to be designed based on a minimum smoke layer / reservoir height of 2m above the highest floor level. Similarly, the New Zealand Building Code[10] requires tenability criteria to be measured at 2m above floor level.

Tenability criteria	Limiting value	Comment
Visibility to a non-illuminated surface	10m 5m	(OD = 0.1m^{-1}) for large enclosures and long travel distances (OD = 0.2m^{-1}) for small enclosures, short travel distances and while queuing at exits – ie once wayfinding is complete[11, 12].
Convected heat	60°C	for long exposure [11, 12]
Heat radiation	2.5kW/m^2	A tenability criterion of 2.5kW/m^2 is adopted for radiation. Long term exposure above this limit exposure can result in severe pain to occupants. This equates to a temperature of 200ºC for a black body emitter, and as such the smoke layer must not exceed this temperature above evacuation routes[11, 12].

[9] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London.
[10] New Zealand Department of building and housing, 2012, C/VM2, Verification method: Framework for fire safety design, New Zealand.
[11] Purser DA, 2008, Assessment of hazards to occupants from smoke, toxic gases, and heat, Chapter 2-6 of the SFPE Handbook of Fire Protection Engineering, 4th edn, SFPE, Bethesda MD.
[12] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London.

Tenability criteria	Limiting value	Comment
Toxicity	NA	CIBSE Guide E states that toxicity limits are unlikely to be exceeded for 'pre-flashover well-ventilated fires'. A tenability limit for visibility of 6m – to non reflecting surfaces – is unlikely to contain irritants at concentrations high enough to seriously inhibit escape or cause collapse. A visibility of 1.5m is likely to represent the safe toxic limit, however escape under these conditions is unrealistic. On this basis, toxicity is not explicitly assessed because the tenability criterion for visibility is expected to be exceeded first[12].

Table 11 Tenability criteria for evacuating occupants

6.4.4 Firefighters

The tenability acceptance criteria proposed firefighters in full turnout gear are identified in Table 12[13].

Tenability criteria	Limiting value
Heat radiation	3kW/m^2 at 1.5m above floor level for areas outside the direct vicinity of the fire.
Convected heat	120°C at 1.5m above floor level for areas outside the direct vicinity of the fire.

Table 12 Tenability criteria for firefighters in full turnout gear

6.5 Fire hazards

6.5.1 Layout

Lower ground floor

The lower ground floor below the heritage void is a lobby for hotel guests arriving by tour bus. Occupants arriving by bus would enter the hotel via the entry at the northern end of the floor.

The floor is served by two exits at the southern and northern end. The exit to the northern end discharges into the bus bay parking on Slip Street from where occupants can travel via a designated path to open space. The designated path is shown by line marking.

The exit to the southern end is into the loading dock from where occupants can travel via a designated path to open space in the southerly direction.

Ground floor

The majority of exits serving the general public in the southern ground floor is via the main entries into the hotel from Sussex Street with supplementary exits to the west via the bridge link to Darling Harbour and to the north into fire compartment 2 from where occupants can evacuate the building via the northern lobby into Sussex Street.

The area where extended travel distances occur is from the all day dining restaurant. Occupants in this area are expected to be able to easily locate the exits from the restaurant as it adjoins the main hotel lobby which is the route they would have taken to enter the restaurant. In addition, it is also the main circulation space into and around the building.

Mezzanine floor

The pre-function south area on the mezzanine floor forms part of fire compartment 1. The area is provided with four exits being the main non-fire isolated feature stair leading to the ground floor lobby, a fire isolated stair adjacent to the lift lobby and two horizontal exits, one to the south and one to the north into fire compartments 3 and 4 respectively.

[13] Fire Brigade Intervention Model, 2004, version 2.2, Australian Fire Authorities Council, Australia.

The majority of occupants in the pre-function space are expected to utilise the main feature stair as an exit in the event of a fire as it is likely to be the route which was taken to enter the space. In the event that the main feature stair is blocked by a fire from the ground floor below, occupants may utilise the alternative exits to the adjoining fire compartments from where multiple exits are available to discharge them outside the building.

6.5.2 Fire load

The majority of fire compartment 1 is lobby / circulation space for hotel use and no significant storage of items is expected within this space. To reduce the risk of a fire impacting on the compartment, all plant rooms and store rooms on the lower ground, ground and mezzanine floors – including luggage and bag stores – are proposed to be fire separated from the remainder of the floor with one hour fire rated construction and self-closing fire doors as these are the areas that are likely to contain the highest fire loads.

The back of house area on the lower ground floor is also proposed to be separated by two hour fire rated construction.

Furnishings and contents make up the majority of fuel load in the all day dining restaurant. Furnishings may include items such as chairs, tables, sofas. These combustibles comprise a combination of wood, paper, metal, thermoplastics, fabric and foam materials.

The restaurant kitchen will be separated from the remainder of the building by construction which prevents the free passage of smoke. This separation can be expected to limit significant smoke spread onto the remainder of the floor in the event of a fire in the back of house / kitchen area.

6.5.3 Sprinkler system

Impact of sprinklers

The lower ground, ground and mezzanine level of the redeveloped building will be protected by a sprinkler system complying with the requirements of specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire[14,15,16].

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

Full scale tests have shown that standard sprinklers can be expected to maintain tenable conditions in relation to temperature and toxicity outside the room of fire origin. Fast response sprinklers have been shown in most instances to maintain a survivable atmosphere in the room of fire origin[17,18].

[14] England JP, Young SA, Hui MC and Kurban N, 2000, Guide for the design of fire resistant barriers and structures, Warrington Fire Research Australia and Building Control Commission, Melbourne VIC.
[15] Technical Memoranda TM19:1995 – Relationships for smoke control calculations, CIBSE, London UK.
[16] Lougheed GD, 1997, Expected size of shielded fires in sprinklered office buildings, ASHRAE Transactions, vol 103, pt 1, pp 395-410.
[17] Madrzykowski D, 1991, NISTIR 4631 – The reduction in fire hazard in corridors and areas adjoining corridors provided by sprinklers, Building and Fire Research Laboratory NIST, Gaithersburg MD.
[18] Fire protection handbook, 2008, 20th edn, NFPA, Quincy MA, pp 20-151.

Data collected in the US demonstrates that 'when sprinklers are present, the chances of dying in a fire are reduced by one-half to three-fourths, and the average property loss per fire is cut by one-half to two-thirds, compared to fires where sprinklers are not present'[19]. Research indicates that when fatalities do occur in sprinkler protected buildings, the victims tend to be in close proximity to the fire, intimate with ignition or incapable of self-preservation[20].

CIBSE Guide E[21] notes the following potential concessions for buildings protected by sprinklers:

- Building compartment areas / volumes may be increased over that for a similar non-sprinklered building.
- A structural element is liable to maintain its load-bearing capacity, and that a separating element will maintain both its integrity and its ability to resist the transfer of heat. The fire resistance levels may therefore be reduced if sprinklers are fitted.
- The distance required to travel to an exit can potentially be increased without reducing the level of safety to people.

Statistics on US experience with sprinklers show that 88% of fires are controlled by one or two heads when sprinklers were effective[22]. Data provided by Marryatt concludes that 92% of fires are controlled by 1-5 heads[23].

Sprinkler system reliability

Sprinkler systems have been demonstrated to achieve high operational reliability through numerous statistical studies. The mean reliability of sprinkler systems was estimated to be 93-96% by Budnick based on analysis of 16 separate studies[24]. Reliability is likely to be even higher where sprinkler systems are provided with redundant water supplies and correctly designed, commissioned and maintained.

The building is provided with a grade 1 water supply. A reliable sprinkler system means that the probability of a fire spreading beyond the area of origin and not being controlled by the sprinklers is low.

Sprinkler failure

The presence of a reliable sprinkler system means that the probability of a fire not being controlled by the sprinklers is low and the fire safety systems are not intended to be designed to deal with the consequences from this unlikely scenario. The sprinkler system is to be regularly maintained in accordance with the relevant Australian Standards to ensure an adequate level of reliability for the system.

In the unlikely event of a fire occurring which is not suppressed by staff or patrons during the growth stage, rapidly developing into a significant uncontrolled fire, the smoke exhaust system and smoke and fire separation is expected to limit the spread of smoke throughout the building.

Additional management-in-use procedures have been identified in section 5.6 in the event the sprinkler system is isolated or turned off to further minimise the risk to occupant safety. Maintenance to the system is to as far as practically possible be restricted to off peak hours. If system shutdown is required, either additional fire separation or detailed management procedures must be incorporated depending on the duration of the shutdown.

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[19] Rohr KD and Hall Jr JR, 2005, US experience with sprinklers and other fire extinguishing equipment, Fire Analysis and Research Division NFPA, Quincy MA.
[20] Fire protection handbook, 2008, 20th edn, NFPA, Quincy MA.
[21] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London.
[22] Hall Jr JR, 2013, US experience with sprinklers and other fire extinguishing equipment, Fire Analysis and Research Division NFPA, Quincy MA.
[23] Marryatt HW, 1988, Fire: A century of automatic sprinkler protection in Australia and New Zealand 1886-1986, Australian Fire Protection Association, Melbourne VIC.
[24] Budnick EK, 2001, Automatic sprinkler system reliability, Fire Protection Engineering, Winter 2001, issue 9, pp 7-12.

6.5.4 Smoke detection

The lower ground, ground and mezzanine floors are proposed to be provided with smoke detection in accordance with AS 1670.1-2004. Activation of a smoke detector will operate the sound system and intercom system for emergency purposes (SSISEP) which is provided with a pre-recorded evacuation message. AS 1670.1-2004 requires that smoke detectors are spaced so that no point on a level ceiling is more than 7.2m from a detector, with at least one detector provided in each partitioned room.

The proposed smoke detection system provides a clear benefit in terms of early warning with the reduced spacing.

6.6 Fire scenario

6.6.1 Selection of fire scenarios

The selection of appropriate fire scenarios is a critical element of any fire safety engineering assessment. The number of scenarios selected is dependent on the scope of the project and the method of assessment. The following factors must be taken into consideration when selecting credible design fire scenarios:

- likelihood of occurrence
- potential consequences
- impact on the issues being assessed.

Considering the fire hazards identified in section 6.5 and the criteria described above, the following credible design fire scenario has been selected to be quantitatively analysed:

Design fire scenarios

CIBSE Guide E[25] suggests a medium growth rate for occupancies such as hotel receptions and picture galleries. It also suggested a slow-medium growth rate for display areas. Therefore, a medium t^2 growth rate is considered applicable for the proposed design fire scenarios.

1. A fire centrally located in the hotel lobby of the heritage void on the lower ground floor – medium t^2 fire growth rate to 1.5MW as required by a sprinklered general class 9 building under specification E2.2b of the BCA.
2. A fire located in the bar on the ground floor – medium t^2 fire growth rate until sprinkler activation.
3. A fire located in the main southern lobby below the void to the mezzanine – medium t^2 fire growth rate to 1.5MW as required by a sprinklered general class 9 building under specification E2.2b of the BCA.
4. A fire located in the southern prefunction area on the mezzanine floor - medium t^2 fire growth rate until sprinkler activation.

Sensitivity fire scenarios

5. A fire located in the bar on the ground floor – medium t^2 fire growth rate until sprinkler control upon activation of the second row of sprinkler heads.
6. A fire centrally located in the hotel lobby of the heritage void on the lower ground floor – medium t^2 fire growth rate to 1.5MW as required by a sprinklered general class 9 building under specification E2.2b of the BCA with a single smoke curtain failing on the ground floor.

It is noted that the fire scenarios incorporate a degree of conservatism as it is assumed the sprinkler system within the building maintains the heat release rate at sprinkler activation rather than suppressing the fire.

The locations of the various fire scenarios are identified in Figure 30, Figure 31 and Figure 32.

[25] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London, Table 6.2

Although kitchen, toilet areas and other back-of-house areas present credible fire hazards within the building, it is considered that the fire scenarios identified represents the worst-credible case as it could lead to direct smoke spread in the main occupied areas. Potential fires in the kitchen, toilet areas and other back-of-house areas are therefore not proposed to be further quantified in this assessment.

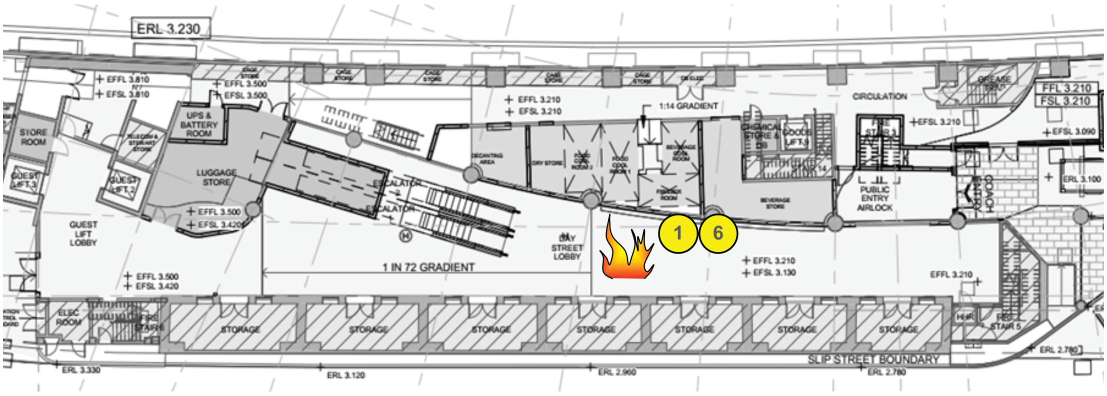


Figure 30 Fire scenario locations – lower ground floor

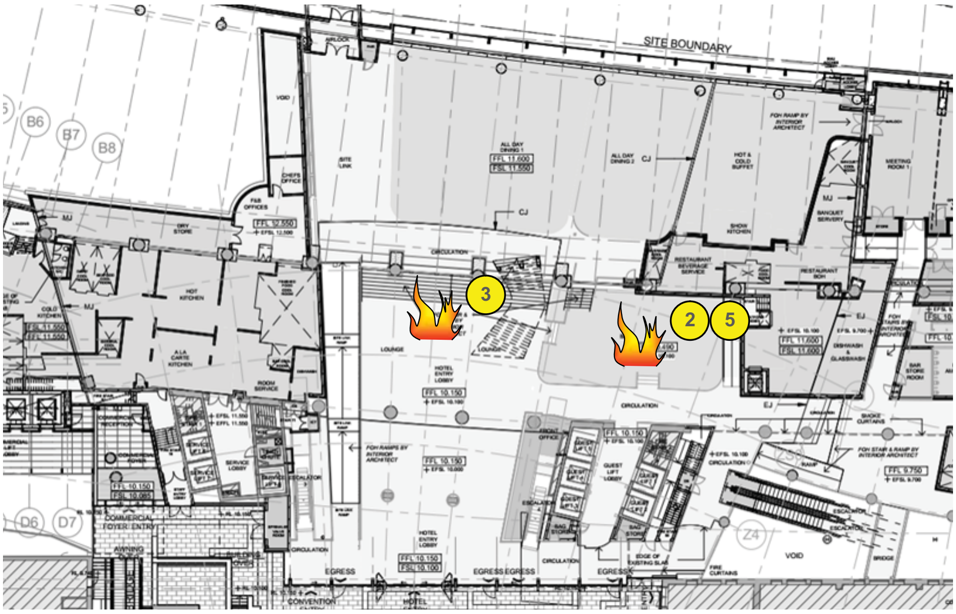


Figure 31 Fire scenario locations – ground floor

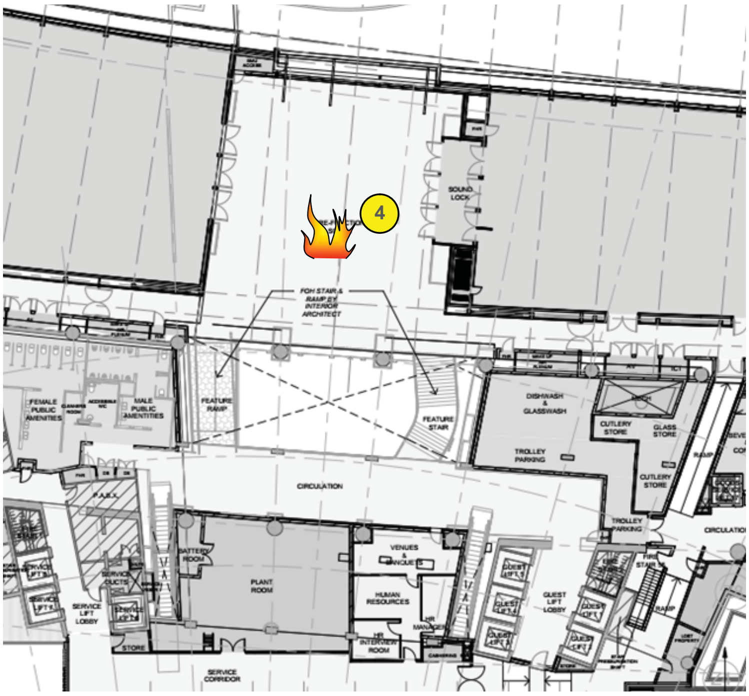


Figure 32 Fire scenario locations – mezzanine floor

6.6.2 Selection of design fire

Design fire assumptions

In order to carry out a quantitative fire safety assessment it is necessary to describe the fire scenarios as 'design fires' by specifying parameters such as heat release and time. The design fire provides the basis for calculation fire and smoke characteristics used to evaluate the tenability criteria. It is noted that the incipient phase of fire development is generally ignored for conservatism.

The following assumptions have been incorporated into the characterisation of the design fires used for the assessment of the building:

- The incipient phase of fire development is ignored for conservatism.
- The time for activation of the sprinkler system within the building has been based upon a fast-response sprinkler system with a response time index (RTI) of 50(ms)$^{1/2}$, activation temperature of 68°C and a sprinkler head spacing of 3.5m x 3.5m.
- The sprinkler system within the building has conservatively been assumed to control the fire – ie maintain the heat release rate at sprinkler activation – rather than suppressing the fire.
- The fire is in the centre of four heads – ie worst case location in terms of distance to a head.
- The base of the fire is assumed to be 0.5m above the floor level to account for a degree of vertical fire spread.

Design fire characteristics

The time for activation of the sprinkler system within the relevant areas being assessed has been determined using Alpert's correlation[26] and research into the heat loss effect of thermal response of automatic sprinklers[27]. The input values used in the modelling of the sprinkler controlled design fires are shown in Table 13 and the output data is attached in Appendix E.

For fire scenarios 1 and 6 – fire within the lower ground floor heritage void – a 1.5MW is proposed to be assessed as required by a sprinklered general class 9 building under specification E2.2b of the BCA. This is considered appropriate given the use of the space as a lobby / circulation area for checking in hotel visitors. The same fire size is also proposed to be adopted for fire scenario 3 – fire within the southern ground floor lobby below the mezzanine void – given this is also a lobby / circulation space providing access between the check-in desks and the restaurant area.

Fire location	Growth rate (kW/s^2)	Height above fire (m)	Activation time (s)	Fire size calculated / modelled (MW)	
Scenarios 1 and 6 – Fire within the lower ground floor heritage void	Medium	-	-	-	**1.5**
Scenario 2 – Fire within the ground floor bar	Medium	3.4	298	0.99	**1.0**
Scenario 3 – Fire within the southern ground floor lobby below the mezzanine void	Medium	-	-	-	**1.5**
Scenario 4 – Fire within mezzanine southern pre-function	Medium	3.9	322	1.15	**1.2**
Sensitivity scenario 5 – Fire within the ground floor bar – 2nd row sprinkler activation	Medium	3.4	461	2.36	**2.36**

Table 13 Calculation of sprinkler activation and maximum heat release rates

6.7 Smoke modelling

6.7.1 CFD smoke modelling

The ASET for the class 9b portions within the heritage void, the main hotel lobby on the ground floor, the southern mezzanine pre-function is determined by modelling the development of untenable conditions within the relevant sections of the building. This involves modelling smoke production and spread with respect to fire size and time. The ASET values are determined for the building based on the output of the modelling conducted to predict smoke generation and movement.

CFD was used to model smoke generation and movement. The CFD program used for this modelling was Fire Dynamics Simulator (FDS) version 5. This program has been developed by National Institute of Science and Technology (NIST) in the United States, for the purposes of modelling smoke and fire in buildings and outdoors. A full description of the CFD modelling conducted is included in Appendix E.

[26] Alpert RL, 1972, Calculation of response time of ceiling mounted fire detectors, Fire Technology, 8(3), pp 181-195.
[27] Heskestad G and Bill RG, 198, Conduction heat-loss effect on thermal response of automatic sprinklers, Fire Safety Journal, v.14, pp 113-125.

6.7.2 Smoke modelling results – ASET

The results of the smoke modelling for the building are summarised in Table 14 with the output data attached in Appendix E.

Fire scenario	Area considered	ASET (minutes)	Criteria	Comment
1. Medium t^2 fire – lower ground floor below heritage void	Lower ground	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
	Ground (heritage void)	>20 >20 5	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	Visibility at the northern end of the heritage void on the ground floor has dropped below 10m after between 4 and 5 minutes.
2. Medium t^2 fire – ground floor bar	Ground (south lobby)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	Visibility within the majority of the hotel lobby is in excess of 10m up to 10 minutes. Beyond 10 minutes, visibility in some areas of the lobby has dropped below 10m however it is still considered tenable for queuing.
	Ground (restaurant)	>20 >20 6.5	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	Visibility within the restaurant has dropped below 10m between 6 and 7 minutes.
	Mezzanine (south pre-function)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
3. Medium t^2 fire to 1.5MW – ground floor below southern void	Ground (south)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
	Mezzanine (south pre-function)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
4. Medium t^2 fire – mezzanine floor southern pre-function	Ground (south)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
	Mezzanine (south pre-function)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.
5. Sensitivity - medium t^2 fire with second row sprinkler activation – ground floor bar	Ground (south)	>20 >20 8.5	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	Visibility within the southern ground floor lobby has dropped below 10m after 8.5 minutes.
	Ground (restaurant)	>20 >20 7	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	Visibility within the all day dining restaurant has dropped below 10m between 6 and 7.5 minutes.
	Mezzanine (south pre-function)	>20 >20 >20	Heat flux 2.5kW/m² Smoke temp 60°C Visibility 10m	No loss of tenability.

Fire scenario	Area considered	ASET (minutes)	Criteria	Comment
6. Sensitivity - medium t^2 fire – lower ground floor below heritage void – smoke curtain failure	Lower ground	>20 >20 >20	Heat flux 2.5kW/m^2 Smoke temp 60°C Visibility 10m	No loss of tenability.
	Ground (heritage void)	>20 >20 5	Heat flux 2.5kW/m^2 Smoke temp 60°C Visibility 10m	Visibility within the heritage void on the ground floor has dropped below 10m after 4 minutes.
	Ground (south lobby)	>20 >20 >20	Heat flux 2.5kW/m^2 Smoke temp 60°C Visibility 10m	Tenability is maintained throughout the hotel lobby in excess of 20 minutes. Visibility in the corridor directly adjacent to the smoke curtains separating the heritage void dropped below 10m after 9 minutes.

Table 14 Summary of smoke modelling results

6.7.3 Calculated evacuation time – RSET

The results of the evacuation assessment for the building are summarised in Table 15. A full description of the evacuation assessment and calculations are attached in Appendix G.

Fire scenario	Area considered	Cue type	Cue period (minutes)	Movement period – including distributed pre-movement (minutes)	RSET (minutes)
Scenario 1 – heritage void	Lower ground floor	Alarm + intrinsic	1	2.1	**3.1**
	Ground floor (heritage void)	Alarm + intrinsic	1	2	**3**
Scenarios 2, 3 and 5 – ground south	Ground floor (south)	Alarm + intrinsic	1	5	**6**
	Ground floor (restaurant)	Alarm + intrinsic	1	2.5	**3.5**
	Southern mezzanine pre-function	Alarm + intrinsic	1	3	**4**
Scenario 4 – mezzanine south	Ground floor (south)	Alarm	1	5	**6**
	Southern mezzanine pre-function	Alarm + intrinsic	1	2.5	**3.5**
Scenario 6 – heritage void	Lower ground floor	Alarm + intrinsic	1	2.1	**3.1**
	Ground floor (heritage void)	Alarm + intrinsic	1	2	**3**
	Ground floor (south)	Alarm	1	5	**6**

Table 15 Evacuation times

6.7.4 Comparison of ASET / RSET

A comparison of the ASET / RSET margin for the scenarios assessed are summarised in Table 16. The ASET / RSET margin for the assessed areas exceeds the acceptance criteria specified in section 6.4.

Fire scenario	Area considered	ASET (minutes)	RSET (minutes)	ASET / RSET	
1. Medium t^2 fire – lower ground floor below heritage void	Lower ground	>20	3.1	**6.4**	(> 1.5)
	Ground (heritage void)	5	3	**1.6**	(>1.5)
2. Medium t^2 fire – ground floor bar	Ground (south lobby)	>20	6	**3.3**	(> 1.5)
	Ground (restaurant)	6.5	3.5	**1.8**	(>1.5)
	Mezzanine (south pre-function)	>20	4	**5.0**	(> 1.5)
3. Medium t^2 fire to 1.5MW – ground floor below southern void	Ground (south)	>20	6	**3.3**	(> 1.5)
	Mezzanine (south pre-function)	>20	4	**5.0**	(> 1.5)
4. Medium t^2 fire – mezzanine floor southern pre-function	Ground (south)	>20	6	**3.3**	(> 1.5)
	Mezzanine (south pre-function)	>20	3.5	**5.7**	(> 1.5)
5. Sensitivity - medium t^2 fire with second row sprinkler activation – ground floor bar	Ground (south)	8.5	6	**1.4**	(> 1.0)
	Ground (restaurant)	7	3.5	**2.0**	(> 1.0)
	Mezzanine (south pre-function)	>20	4	**5..0**	(> 1.0)
6. Sensitivity - medium t^2 fire – lower ground floor below heritage void – smoke curtain failure	Lower ground	>20	3.1	**6.4**	(> 1.0)
	Ground (heritage void)	5	3	**1.6**	(> 1.0)
	Ground (south lobby)	>20	6	**3.3**	(>1.0)

Table 16 Comparison of ASET / RSET

6.8 Fire brigade intervention

The smoke modelling performed demonstrated that temperatures within the sprinkler protected building remain below 60°C for the duration of the simulation with the exception of the region immediately surrounding the fire. These temperatures are consistent with expected compartment temperatures in the event of sprinkler controlled fires.

These temperatures are below the tenability limits for attending firefighters with the exception of the localised area around the fire. It is therefore considered the design facilitates fire brigade intervention to the degree necessary to achieve compliance with the performance requirements of the BCA.

6.9 Redundancy analysis

6.9.1 Mechanical smoke exhaust

The mechanical smoke exhaust system provided throughout fire compartment 1 on the lower ground, ground and mezzanine floor is considered to have a similar level of redundancy to that of a DTS complying design.

To ensure an adequate level of reliability the smoke exhaust system must be regularly maintained in accordance with the relevant Australian standards.

6.9.2 Exit provisions

The assessment provided in Appendix G has taken into consideration partial failure of the exits provided and its impact on occupant evacuation – ie through the blockage of some exits.

6.10 Conclusion

The assessment demonstrates that the proposed design of the building facilitates safe occupant egress and fire brigade intervention in the event of a fire. The proposed design of the building is therefore considered to achieve compliance with performance requirements DP4 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

7. Alternative solution 2 – Extended travel distances on the northern ground floor

7.1 Introduction

Clause D1.4(c)(i) of the BCA states that 'no point on a floor must be more than 20m from an exit, or a point from which travel in different directions to two exits is available, in which case the maximum distance to one of those exits must not exceed 40m'.

The northern part of the ground floor – which is not required and not provided with smoke exhaust – includes travel distances in excess of the requirements of clauses D1.4 of the BCA. The proposed design incorporates the following maximum travel distances:

- Travel distance to a point of choice up to a maximum of 30m in lieu of 20m.
- Travel distance up to a maximum of 50m in lieu of 40m.

This assessment was undertaken to demonstrate that the design complies with performance requirements DP4 and EP2.2 of the BCA.

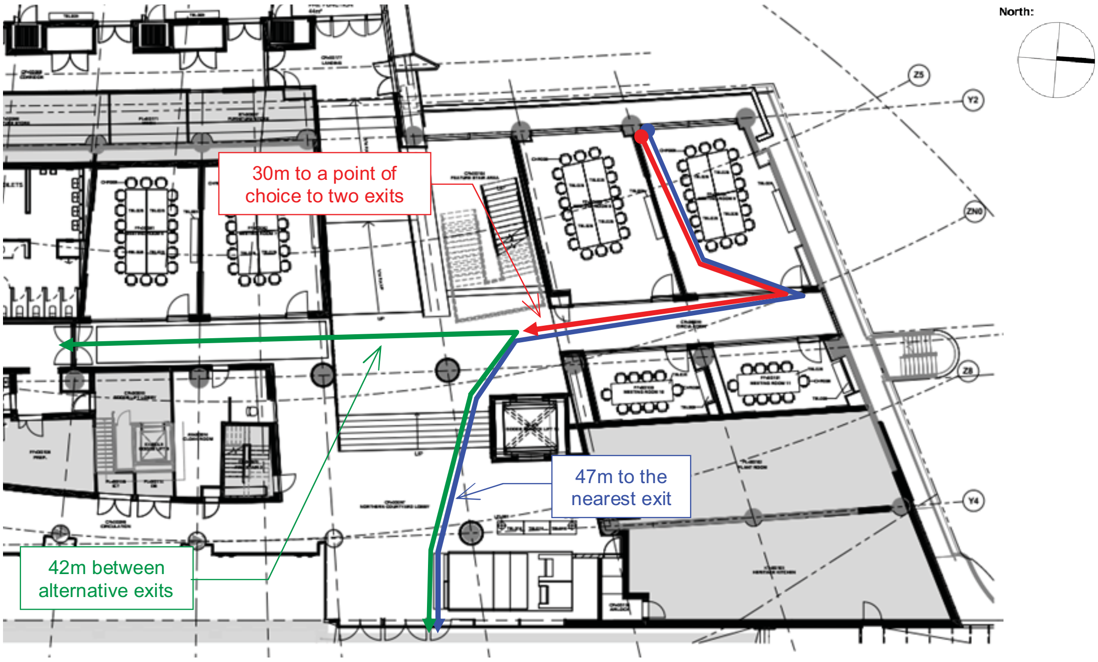


Figure 33 Travel distances on northern ground floor

7.2 Intent of the BCA

7.2.1 Travel distances – clause D1.4

The Guide to the BCA states that the intent of clause D1.4 is 'to maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate.' The guide explains that 'the clause D1.4 travel distances are based on an assumption of what is considered 'reasonable' distances to be travelled by occupants in reaching an exit.'

The guide elaborates on the intent of the travel distance to a single exit or point of choice requirement where people are assumed to be alert and awake. 'Clause D1.4(c)(i) sets out the maximum travel distance in class 5-9 buildings. The distances specified allow people to evacuate in a reasonable time, assuming that they are not asleep. In case a fire blocks a path of travel, clause D1.4(c)(i) requires that alternative routes must be available within 20m of the starting point, unless it is possible to reach a single exit within 20m.'

7.3 Methodology

The assessment undertaken for the building was a quantitative comparative assessment supported by qualitative assessment involving the following sub-systems:

- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control

7.4 Acceptance criteria

The acceptance criteria for the assessment are that the available safe evacuation time (ASET) / required safe evacuation time (RSET) margin arising from the proposed building design is at least equivalent to the corresponding margin arising from the base case. The base case design is considered to provide a representative level of life safety required by the DTS provisions of the BCA.

The ASET / RSET timeline is illustrated in Figure 29.

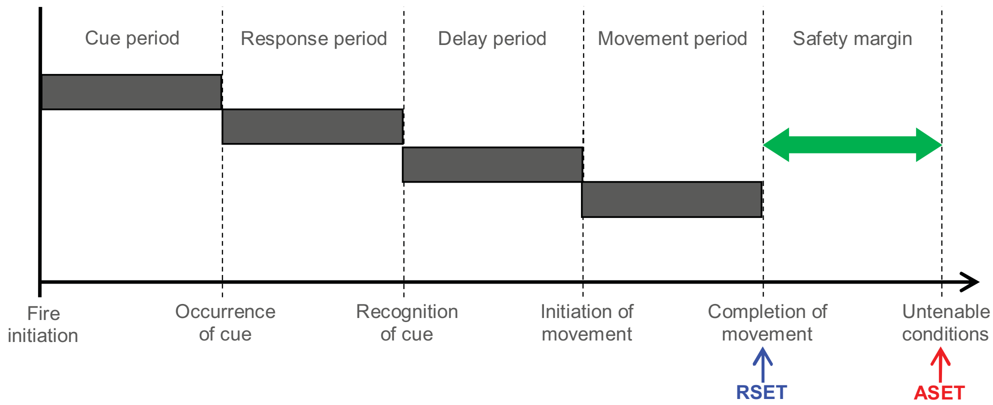


Figure 34 ASET / RSET timeline

7.5 Fire hazards

7.5.1 Travel distances

The hazard associated with the extended travel distances within the building must be assessed in terms of the ability of the occupants to safely undertake an evacuation should a fire occur. The reason that clause D1.4 of the BCA stipulate travel distance requirements is to ensure that all occupants of the building are within a reasonable distance of an exit so that they can safely evacuate in the event of a fire.

The requirement relating to travel distance to the point of choice is intended to allow occupants to reach the point of choice prior to the path of travel becoming blocked.

The intent of the alternative solution is to demonstrate that the provision of an AS 1670.1-2004 smoke detection system allows occupants to reach the point of choice and nearest exit in an at least equivalent time to occupants of a similar building with AS/NZS 1668.1:1998 spaced detection system and complying travel distances.

7.5.2 Layout

The majority of exits serving the general public in the northern ground floor is via the exits into the northern courtyard on the eastern perimeter which lead to Sussex Street. A supplementary horizontal exit to the south into fire compartment 1 is also available from where occupants can evacuate the building via the main lobby into Sussex Street.

The area where extended travel distances occur is from meeting rooms 8, 9 and 11. Occupants in this area are expected to be able to easily locate the exits from the meeting rooms as they adjoin the northern hotel lobby which is the route they would have taken to enter the meeting rooms.

7.5.3 Fire load

The northern part of the ground floor is within fire compartment 2. The floor is comprised of six meeting rooms and lobby / circulation space for occupants to use before and after entering the meeting rooms. The lobby space contains limited combustibles and there is no significant storage of items expected within this space apart from a cloak room.

To reduce the risk of a fire impacting on the northern ground floor, the adjoining plant room and heritage kitchen is proposed to be fire separated from the remainder of the floor with two hour fire rated construction and self-closing fire doors as these are the areas that are likely to contain the highest fire loads. This separation can be expected to limit significant smoke spread onto the remainder of the floor in the event of a fire in the plant / kitchen area. The provision of sprinkler protection through the building can be expected to mitigate the risk of fire spread and further reduce smoke spread onto the public floor areas.

7.6 Design characteristics for comparison

The proposed design of the northern ground floor area complies with the DTS provisions of the BCA except for the specific alternative solutions described within section 3.4 of this report. The proposed design will be compared to a base case building that complies with the DTS provisions of the BCA. The base case building is similar in layout to the proposed design of the northern ground floor. The main differences between the designs are the travel distances and smoke detection system within the building.

A comparison between the key building characteristics of the proposed design and the base case design within the northern ground floor is provided in Table 17.

Characteristic	Proposed design (alternative solution)	Base case (DTS complying)
Travel distance to a point of choice	30m	20m
Travel distance to the closest exit	50m	40m
Travel distance between alternative exits	60m	60m
Population	486 persons	486 persons
Aggregate exit width	5m via northern courtyard exits	5m via northern courtyard exits
Effective height	>25m	>25m
Sprinkler system	Yes – fast response	Yes
Smoke detection	In accordance with AS 1670.1-2004 – ie 10.2m grid layout for smoke detectors.	In accordance with AS/NZS 1668.1-1998 (for operation of zone smoke control and stair pressurisation) – ie 20.4m grid layout for smoke detectors.
Building occupant warning system	Sound system and intercom system for emergency purposes	Sound system and intercom system for emergency purposes

Table 17 Comparison of proposed design and base case

Note: The population assessed includes the full capacity of meeting rooms 1 to 5 from the adjoining fire compartment 5. This is to account for their potential presence in the northern lobby during pre-function / waiting periods between meetings.

7.7 Fire scenario

7.7.1 Selection of fire scenarios

The selection of appropriate fire scenarios is a critical element of any fire safety engineering assessment. The number of scenarios selected is dependent on the scope of the project and the method of assessment. The following factors must be taken into consideration when selecting credible design fire scenarios:

- likelihood of occurrence
- potential consequences
- impact on the issues being assessed.

Considering the fire hazards identified in section 7.5 and the criteria described above, it is proposed to assess a fire within the northern ground floor lobby.

As previously discussed in section 6.6, CIBSE Guide E[28] suggests a medium fire growth rate for occupancies such as hotel receptions and picture galleries. It also suggested a slow-medium growth rate for display areas. Therefore, a medium t^2 growth rate is considered applicable as a representative credible fire growth rate given the types of fuel load expected within the building.

7.7.2 Fire location and detector spacing

The time taken for a smoke detector to activate – amongst other factors – is dependent on the radial distance between the smoke detector and the fire source. The worst case for detector activation occurs at the maximum radial distance from the fire. Detector activations calculated in this assessment are based on the maximum radial distance between the fire and the detector which corresponds to 14.4m for the base case smoke detection system and 7.2m for the proposed design smoke detection system as illustrated in Figure 35.

It is recognised that a fire can occur directly below a smoke detector. In this case, the detector activation time for the base case and proposed design systems will be equivalent. However, the reduced grid spacing of the proposed design smoke detection system in comparison to the base case smoke detection system means that a fire is more likely to be located close to or directly under a detector in the proposed design. A fire located directly below a detector represents the most favourable scenario in terms of having the earliest detector activation time. For these reasons, the scenario of a fire directly under a detector is excluded from the evacuation assessment.

It should also be noted that in a partitioned layout such as this, the AS 1670.1-2004 smoke detection system has a great advantage in requiring not less than one detector per room. In a complying AS/NZS 1668.1:1998 system, smoke may have to spread beyond the room of fire origin before being detected.

[28] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London, Table 6.2

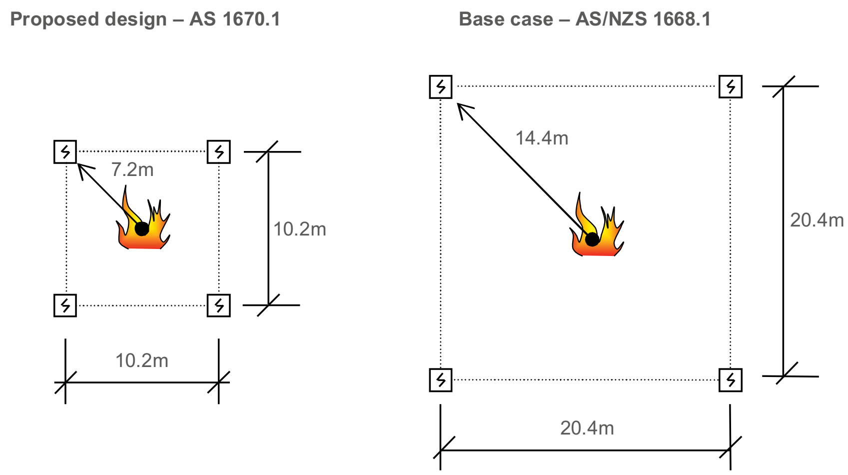


Figure 35 Proposed design and base case detector grid spacing

7.8 Assessment

7.8.1 Available safe evacuation time

The base case for the assessment has the same use, floor area, volume and ventilation as the proposed design. The only factors that vary between the two designs are the increased travel distances as well as the smoke detector spacing. These differences in the two designs will not impact upon the time for untenable conditions to develop within the floor of fire origin.

For this reason the ASET has not been calculated within the assessment. The ASET / RSET margin can therefore be based on the RSET because this is the only factor that varies between the designs.

7.8.2 Required safe evacuation time

The results of the comparative evacuation assessment attached in Appendix H are summarised in Table 18. They indicate that the RSET for the proposed design is less than the RSET calculated for the base case. This is due to the earlier warning provided by the AS 1670.1-2004 smoke detection system. The assessment demonstrates that the expected evacuation time on the floor of fire origin is at least equivalent to a design complying with the DTS provisions of the BCA. The proposed design achieves the acceptance criteria nominated in section 7.4.

It should be noted that this analysis conservatively ignores the advantage of an AS 1670.1 system with at least one detector per room compared to an AS/NZS 1668.1 system where smoke may have to spread from the enclosure of fire origin before being detected.

Building	Measure	Cue period	Pre-movement phase	Movement period	RSET excl. pre-movement phase
Proposed design	Point of choice	48s	Equivalent	30s	**78s**
	Nearest exit	48s	Equivalent	92s	**140s**
DTS compliant base case	Point of choice	92s	Equivalent	20s	**112s (> 78s)**
	Nearest exit	92s	Equivalent	92s	**184s (> 140s)**

Table 18 Comparison of RSETs – based on smoke detection system cue

7.9 Conclusion

The assessment demonstrates that occupants within the proposed northern ground floor are expected to evacuate in an equivalent time to a design that complies with the DTS provisions of the BCA. This is due to the earlier warning provided by the AS 1670.1 smoke detection system.

As the expected time for untenable conditions to develop within the building – for the area of fire origin – is similar to a DTS compliant building the margin between the ASET and RSET for the building is expected to be at least equivalent to the DTS compliant base case even though the travel distances exceed the requirements of clauses D1.4 of the BCA. The proposed design of the northern ground floor is therefore considered to achieve compliance with performance requirements DP4 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

8. Alternative solution 3 – Reduction in aggregate exit width on mezzanine floor

8.1 Introduction

NSW clause D1.6 of the BCA states that 'in a class 9b building used as an entertainment venue, the aggregate width must be not less than 2m plus 500mm for every 50 persons or part in excess of 200.

As part of the construction of the new convention rooms, the mezzanine floor is proposed to cater for up to 1800 persons simultaneously. The mezzanine floor is provided with an aggregate exit width of 13m in lieu of required 18m. To compensate for this shortfall, the horizontal exits between the fire compartments are used to facilitate safe occupant evacuation.

This assessment was undertaken to demonstrate that the design complies with performance requirements DP4, DP6 and EP2.2 of the BCA.

8.2 Intent of the BCA

The Guide to the BCA states that the intent of clause D1.6 is 'to require exits and paths of travel to an exit to have dimensions to allow all occupants to evacuate within a reasonable time.' The guide explains that 'the required exit and path of travel widths have been determined on the basis of an estimate of the width required to allow the safe exit of a given number of people expected in particular buildings.'

8.3 Methodology

The assessment undertaken for the building was a quantitative comparative assessment supported by qualitative assessment involving the following sub-systems:

- Sub-system B – Smoke development and spread and control
- Sub-system C – Fire spread and impact and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control

8.4 Acceptance criteria

The acceptance criteria for the assessment is that required safe evacuation time (RSET) from the fire-affected compartment to a place of safety for the proposed design is at least equivalent to the RSET for a design complying with the DTS provisions of the BCA.

The base case for the assessment has the same use, floor area, volume and ventilation as the proposed design. The only factors that vary between the two designs are reduced aggregate exit widths from the floor and the smoke detector spacing. These differences in the two designs will not impact upon the time for untenable conditions to develop within the floor of fire origin.

For this reason the ASET will not be calculated within the assessment.

8.5 Fire hazards

The specific hazard to be assessed is related to the increased population affecting the emergency evacuation of the mezzanine floor. The mezzanine floor is proposed to cater for up to 1800 persons – including staff – with a limitation of 1100 persons within the southern function room and 1000 persons within the northern function room. It is noted that when the function rooms are at capacity, the corresponding pre-function areas are considered to be empty and do not result in a population increase. Refer to Appendix I for population assumptions.

8.6 Design characteristics

The proposed design complies with the DTS provisions of the BCA except for the specific alternative solutions described within section 3.4 of this report. The proposed design will be compared to a base case building. The base case building is similar in layout to the proposed design of the northern ground floor. The main differences between the designs are the population numbers, smoke detector spacing and the evacuation strategy via horizontal exits.

A comparison between the key building characteristics of the proposed design and the base case design within the mezzanine floor is provided in Table 17.

Characteristic	Proposed design (alternative solution)	Base case (DTS complying)
Population	1800 persons across the mezzanine floor	1300 across the mezzanine floor
Aggregate exit width	13m via a combination of fire isolated and non-fire isolated stairways	13m via a combination of fire isolated and non-fire isolated stairways
Additional exit width (horizontal egress)	Via fire doors between fire compartments 1, 2, 3 and 4 9m between compartment 1 and 3 9m between compartment 1 and 4 7m between compartment 2 and 4	NA
Effective height	>25m	>25m
Sprinkler system	Yes – fast response	Yes
Smoke detection	In accordance with AS 1670.1-2004 – ie 10.2m grid layout for smoke detectors.	In accordance with AS/NZS 1668.1-1998 (for operation of zone smoke control and stair pressurisation) – ie 20.4m grid layout for smoke detectors.
Building occupant warning system	Sound system and intercom system for emergency purposes	Sound system and intercom system for emergency purposes

Table 19 Comparison of proposed design and base case

8.7 Fire scenario

The selection of appropriate fire scenarios is a critical element of any fire safety engineering assessment. The number of scenarios selected is dependent on the scope of the project and the method of assessment. The following factors must be taken into consideration when selecting credible design fire scenarios:

- likelihood of occurrence
- potential consequences
- impact on the issues being assessed.

Considering the fire hazards identified in section 8.6 and the criteria described above, the following credible design fire scenario has been selected to be analysed:

Design fire scenarios

As previously discussed in section 6.6, CIBSE Guide E[29] suggests a medium fire growth rate for occupancies such as hotel receptions and picture galleries. It also suggested a slow-medium growth rate for display areas. Therefore a medium t^2 growth rate is considered applicable as a representative credible fire growth rate given the types of fuel load expected within the building.

[29] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London, Table 6.2

1. A fire centrally located in the southern pre-function area – fire compartment 1 – on the mezzanine floor
2. A fire centrally located in the northern pre-function area – fire compartment 2 – on the mezzanine floor
3. A fire centrally located in the southern function room – fire compartment 3 – on the mezzanine floor
4. A fire centrally located in the northern function room – fire compartment 4 – on the mezzanine floor

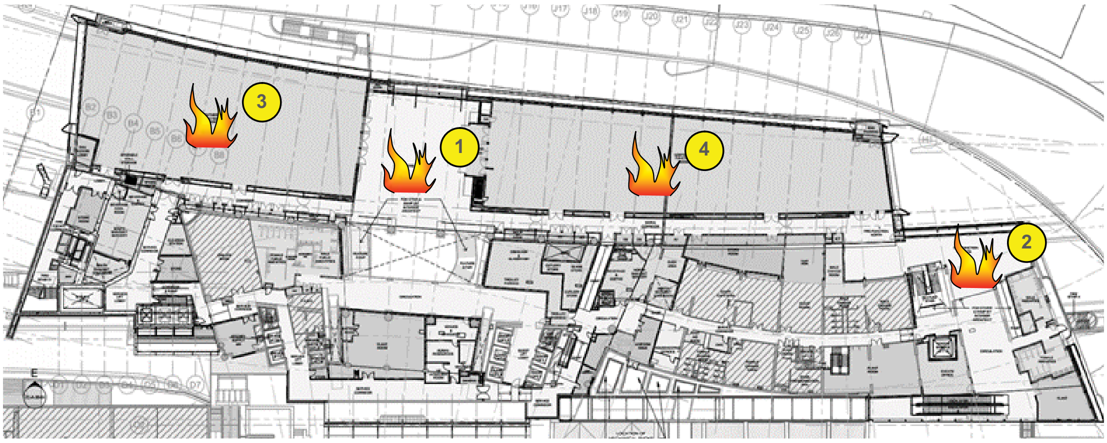


Figure 36 Fire scenario locations – mezzanine floor

8.8 Assessment

8.8.1 Required safe evacuation time

The movement period for occupants on the mezzanine floor for the various fire scenarios have been calculated using Pathfinder. Pathfinder is an agent based egress and human movement simulator that includes 3D results visualisation – refer to Appendix G.4 for further information.

Within the proposed design of the mezzanine floor, a portion of occupants within the compartment of fire origin horizontally egress to the adjacent fire compartments on the floor – depending on the compartment of fire origin. Although the various fire compartments on the mezzanine floor are separate evacuation zones, the modelling assumes all portions are evacuated simultaneously to account for potential interaction between occupants from adjoining compartments – ie it is likely occupants of the non-fire-affected compartments will become aware of the fire incident based on the horizontal egress of occupants from the fire-affected compartment as well as warnings from the EWIS system.

It should be noted that allowing for simultaneous evacuation is conservative. If staged evacuation was implemented, the evacuation times for the compartment of fire origin will be decreased as there will be less impact from the occupants from the adjoining non-fire-affected compartments.

Occupants within the compartment of fire origin are considered to have reached a place of safety when they have evacuated off the mezzanine floor to a non-fire isolated stair, a fire isolated stair, or alternatively to a separate fire compartment via a horizontal exit.

The results of the comparative evacuation assessment are attached in Appendix I and summarised in Table 20. The results indicate that the RSET for the proposed design is less than the RSET calculated for the base case. The assessment demonstrates that the expected evacuation time in the compartment of fire origin is at least equivalent to a design complying with the DTS provisions of the BCA. The proposed design achieves the acceptance criteria nominated in section 8.4.

Scenario	Cue period	Pre-movement phase	Time for last person within compartment of fire origin to reach place of safety (Movement period)	RSET
Base case	92s	Equivalent	254s	**346s**
1. Fire in southern pre-function room (fire compartment 1) – proposed design	48s	Equivalent	162s	**210s (< 346s)**
2. Fire in northern pre-function room (fire compartment 2) – proposed design	48s	Equivalent	150s	**198s (< 346s)**
3. Fire in southern function room (fire compartment 3) – proposed design	48s	Equivalent	247s	**295s (< 346s)**
4. Fire in northern function room (fire compartment 4) – proposed design	48s	Equivalent	211s	**259s (< 346s)**

Table 20 Comparison of RSETs

8.9 Conclusion

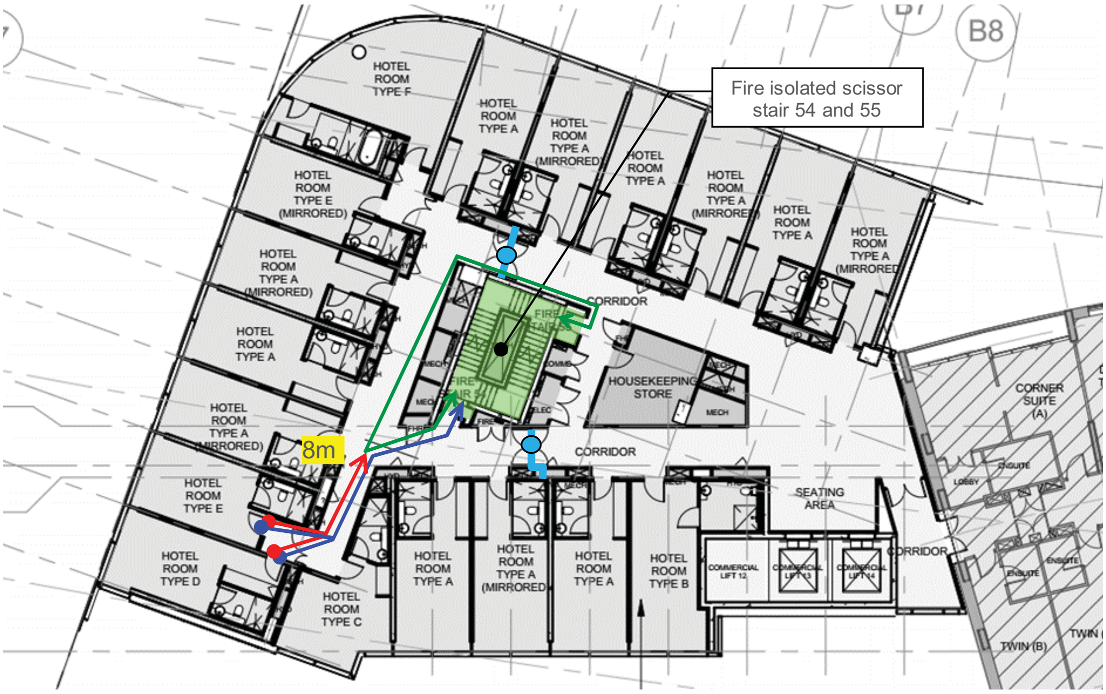
The assessment demonstrates that occupants on the mezzanine floor are able to evacuate to a place of safety in an equivalent time to a design that complies with the DTS provisions of the BCA. This is due to the proposed fire compartmentation providing additional horizontal exits for occupants. The proposed design of the building is therefore considered to achieve compliance with performance requirements DP4, DP6 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

9. Alternative solution 4 – Extended travel distance from hotel rooms

9.1 Introduction

Clause D1.4(a)(i)(A) of the BCA states that 'the entrance doorway of any sole-occupancy unit must be not more than 6m from an exit or from a point from which travel in different directions to two exits is available'.

The proposed design of the residential hotel levels 2 to 15 within the new tower incorporates travel distances of up to 8m from a sole-occupancy unit to a point of choice to two alternative exits as shown in Figure 37.



Legend

- Full height smoke separation
- Self-closing or automatic closing smoke door with smoke seals
- Worst case travel distance to a point of choice (8m)
- Path of travel to an exit
- Path of travel between alternative exits

Figure 37 Levels 2 to 15 typical – hotel tower

This assessment was undertaken to demonstrate that the design complies with performance requirements DP4 and EP2.2 of the BCA.

9.2 Intent of the BCA

9.2.1 Travel distance to a single exit or point of choice – clause D1.4

The Guide to the BCA[30] states that the intent of clause D1.4 is 'to maximise the safety of occupants by enabling them to be close enough to an exit to safely evacuate.' The guide expands further that 'D1.4(a)(i)(A) and (B) require a shorter travel distance, to a single exit, for class 2 and class 3 buildings and class 4 parts than is required for class 5 to class 9 buildings.

The distance occupants of sole-occupancy units in class 2 and class 3 buildings and class 4 parts must travel to leave their unit is not part of the distance specified in D1.4. Accordingly, the permitted distance of travel from the point at which the occupant leaves the unit must take account of the time needed for the occupant to reach that point from within the unit.

Distance of travel must factor in the time occupants need to wake up, become alert to their predicament, and exit in a state of confusion.

This process of becoming alert will inevitably require more time to exit. Therefore the distance of travel to an exit should be shorter.'

It is considered that the travel distance requirement for residential buildings of 6m to a single exit or point of choice also relates to the potential exposure of occupants to a fire affected unit while evacuating. While not directly related to travel distance, increasing the distance to an exit or point of choice increases the risk of the means of escape being obstructed by a fire in an intervening unit. While it is expected that the door to the unit would be closed, a significant amount of smoke is able to leak around the door leaf.

9.3 Methodology

The assessment undertaken for the building was a qualitative and quantitative absolute assessment involving the following sub-systems:

- Sub-system B – Smoke development and spread and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control

9.4 Acceptance criteria

The acceptance criterion for the assessment is that the design facilitates safe occupant evacuation in consideration of the increase in travel time, risk of obstruction and the benefits of AS 1670.1-2004 smoke detectors and sprinklers.

9.5 Fire hazards

9.5.1 Fire load and fire separation

The fire load within the individual sole occupancy units within the hotel floors will comprise furnishings such as beds, chairs, couches, tables and wardrobes.

The public corridors can be expected to contain a low fuel load limited to the floor and wall coverings.

All rooms opening onto the public corridor will be separated by fire rated bounding construction – ie FRL 90/90/90 where loadbearing and -/60/60 where non loadbearing. The doorways to the rooms will be protected by self-closing fire doors achieving an FRL of -/60/30.

[30] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

9.5.2 Travel distances

The primary fire hazard associated with the extended travel distances within the residential portions of the hotel is that the path of travel to an exit along the public corridors is obstructed by a fire occurring in one of the sole occupancy units. This may occur as a result of failure of the fire door to the sole occupancy unit or failure of the fire rated bounding construction. Smoke leakage into the common corridors may also slow or impede occupant evacuation to the point of choice / exit.

The reason that clause D1.4 of the BCA stipulate travel distance requirements is to ensure that all occupants of the building are within a reasonable distance of an exit so that they can safely evacuate in the event of a fire.

The maximum travel distances stipulated in the BCA are notional figures. These requirements are conservative in nature as they relate to all possible design scenarios. They do not take into account the layout of the building or active fire safety systems within the building.

9.5.3 Layout and occupant awareness

Occupants of a class 3 occupancy are likely to be short term residents who are not familiar with the layout of the building or fire safety systems. Although occupants of the subject building may not be familiar with the layout, the floor plate of the new southern hotel tower is relatively small and the exits are located in areas where occupants would ordinarily pass to access their hotel room from the lift.

9.6 Assessment

9.6.1 Occupant evacuation

Observations and experiments have shown that evacuation flow speed of a group is a function of the population density[31,32,33]. If the population density is less than about 0.54 persons/m^2 of exit route individuals will move at their own pace, independent of the speed of others. If the population density exceeds approximately 3.8 persons/m^2, no movement will take place until enough of the crowd has passed from the crowded area to reduce the density. Between the density limits of 0.54 and 3.8 persons/m^2 the relationship can be considered as a linear function. This linear function is given by Equation 1 with Figure 38 showing the relationship between speed and density. The maximum speed occurs when the density is less than 0.54 persons/m^2.

$$S=k-0.266kD$$

where:

S = speed along the line of travel (m/s)

D = density (persons/m^2)

k = constant

Equation 1 Evacuation speed as a function of density

[31] Predtechenskii VM, Milinskii, AI, 1978, Planning for Foot Traffic Flow in Buildings (translated from Russian), Stroizdat Publishers, Moscow, 1978. English translation published for the National Bureau of Standards and the National Science Foundation, Amerind Publishing Co., New Delhi, India.
[32] Fruin JJ, 1971, Pedestrian Planning Design, Metropolitan Association of Urban Designers and Environmental Planners Inc., New York.
[33] Pauls JL, 1980, Effective Width Model for Evacuation Flow in Buildings, in Proceedings, Engineering Applications Workshop, Society of Fire Protection Engineers, Boston.

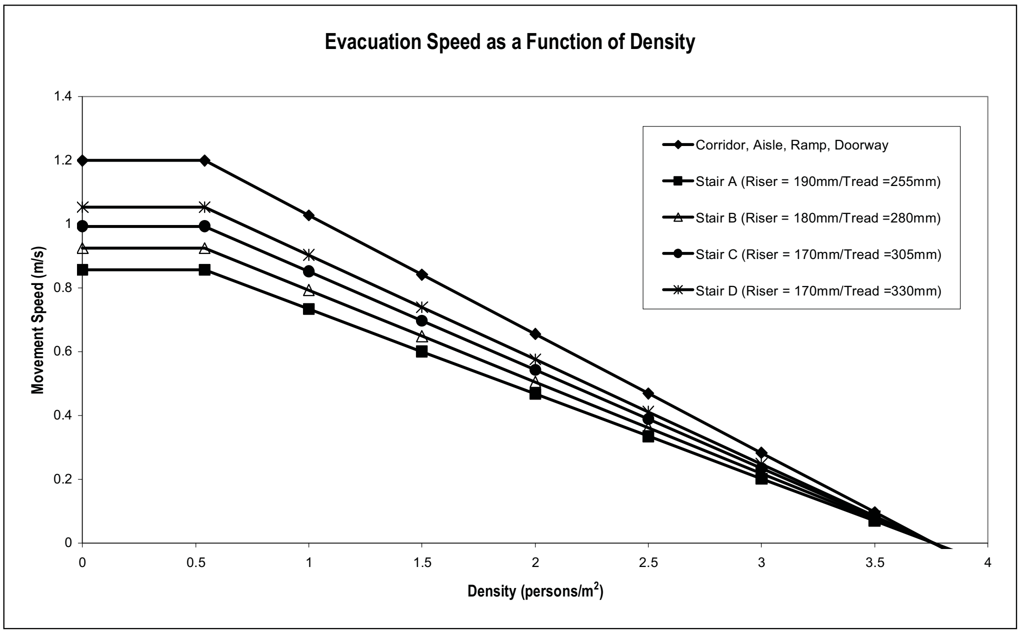


Figure 38 Evacuation speed as a function of density

The population density within a residential building is expected to be less than 1.0 persons/m^2. Travel speeds at 1.0 person/m^2 are approximately 1.0 m/s in corridors. The addition of a maximum of 2m to the travel distance from the sole-occupancy unit to the point of choice will increase the time to reach the point of choice by approximately 2 seconds.

The additional 2 seconds resulting from the increase in travel distance must be considered in conjunction with the likely pre-movement time of the occupants after receiving a cue to evacuate the building. The Fire Code Reform Research Program has published data on the Times to Start Action in response to a cue[34] which is summarised in Table 21. This data was compiled from 53 cases in the Response in Fires Database. The data indicates that the mean and maximum time for occupants in a residential building to investigate the fire and begin evacuation are 220 and 360 seconds respectively when an alarm cue is received and occupants are asleep. Without alarms these times were found to increase to 282 and 1260 seconds respectively.

Taking the minimum and maximum pre-movement times into account for all cases in Table 21, the additional 2 seconds travel time to the exit amounts to between 0.16-5% of the pre-movement time. This indicates that the pre-movement time has a greater impact on the total evacuation time compared to the additional distance of travel to the point of choice.

Furthermore, the CIBSE Guide E refers to evacuation times for residential buildings being up to 30 minutes[35]. This additional 2 seconds travel time to the exit equates to 0.11% of the evacuation time. On this basis, it is considered that the throughout the residential hotel floors in the new tower, the point of choice to two alternative exits is located within a ‘reasonable distance’ of the sole-occupancy units as intended by clause D1.4 of the BCA and that the additional 2 seconds is expected to have minimal impact on the time required for occupants to safely evacuate the floor in the event of a fire.

[34] Fire Code Reform Research Program, February 1997, Response in Fires Database, Technical Report FCRC-TR 97–12.
[35] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, The Chartered Institution of Building Services Engineers London.

Cases & Condition	N	Mean	D.3	25%ile	75%ile	Min. time	Max. time
All	13	282	313	107	345	40	1260
Asleep	8	356	378	152	375	120	1260
Awake	5	165	127	65	300	40	330
70+ year (all asleep)	3	590	590	150		150	1260
<70 years	10	190	112	94	285	40	380
<70, asleep	5	215	102	138	310	120	380
<70, awake	5	165	127	65	300	40	330
Light smoke (all awake)	3	230	125	90		90	330
Alarms	4	175	136	60	315	40	360
Alarm, asleep	3	220	125	120		120	360
Warning (all asleep)	5	437	469	153	820	150	1260

Table 21 Total time from the cue to start of investigation until start of evacuation

9.6.2 Risk of obstruction

The worst case fire scenario for occupants of the hotel rooms located further than 6m from a point of choice to an exit is where another hotel room along the path of travel to the point of choice is on fire. The entry doors to the hotel rooms with extended travel distances to the point of choice to stair 54 and 55 are located at the end of the corridor. If the design of the building was altered so that these doors were located within 6m of the point of choice, occupants would still be required to pass by the other hotel rooms to reach the point of choice. Within the proposed design, the maximum number of entry doors that occupants are required to pass by is 3. This is considered to be consistent with a DTS compliant design with units on both sides of a 6m corridor. Therefore, the increase in the travel distance to an exit from the hotel room will not result in an increased risk of occupants being exposed to another hotel room that is on fire.

9.6.3 Sprinkler protection

The building is proposed to be provided with a sprinkler system in accordance with specification E1.5 of the BCA and AS 2118.1-1999. The sprinkler system is required to be connected to and must activate the sound system and intercom system for emergency purposes (SSISEP) for the building. The provision of sprinklers in the hotel rooms would provide early warning to all occupants in the event that a fire within a hotel room grows to a size and intensity which would cause the system to activate and may threaten the integrity of the room entry door.

9.6.4 Smoke detection in public corridors

The hotel floors on of the new tower will be provided with a smoke detection system in accordance with clause 4 of specification E2.2a of the BCA and AS 1670.1-2004. Under the DTS provisions of the BCA, a concession applies such that smoke detection is not required to be in sprinkler protected class 3 buildings. In the proposed design of the hotel floors in the new southern tower, smoke detection will also be provided within the public corridors of the hotel floors.

The addition of smoke detectors in the public corridors of the hotel floors is considered to provide additional benefit in providing early warning to all occupants in the event of a fire within a hotel room which spreads smoke into the common corridor. In a DTS-complying design where smoke detectors are exempt from public corridors, occupants in adjoining rooms may not become aware of a fire or smoke which has spread into the public corridor until activation of the sprinkler system.

The additional 2m of travel distance to a point of choice is considered to be offset by the earlier warning provided by the addition of smoke detectors in the public corridors in the event that smoke spills into the corridor from an adjoining sole-occupancy unit.

9.7 Conclusion

The assessment undertaken for the proposed design demonstrates that the hazard associated with the extended travel distance is mitigated and facilitates safe occupant evacuation considering the fire safety measures provided to protect the path of travel from the units to the point of choice. The proposed design of the building is therefore considered to achieve compliance with performance requirements DP4 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

10. Alternative solution 5 – Reduction in FRLs of all day dining and kitchen on ground floor

10.1 Introduction

Clause C1.1 of the BCA requires that the building must comply with the requirements of specification C1.1 for type A construction. Table 3 of specification C1.1 of the BCA stipulates that class 6 portions achieve an FRL of not less than 180/180/180.

It is proposed to reduce the fire resistance of the ground floor all day dining restaurant and kitchen areas from 180 minutes to 120 minutes. The relevant area is shown in Figure 39. As clauses C2.8 and C2.9 of the BCA refer to the separation of classifications in the same storey and in different storeys respectively, the proposed design also does not comply with the following provisions:

- The fire separation between the restaurant and hotel portions the ground floor is not provided for the purposes of separation between classifications.
- The fire separation between the restaurant on the ground floor and the convention rooms on the mezzanine floor above includes a floor slab achieving an FRL of 120/120/120 in lieu of 180/180/180.

This assessment was undertaken to demonstrate that the design complies with performance requirements CP1 and CP2 of the BCA.

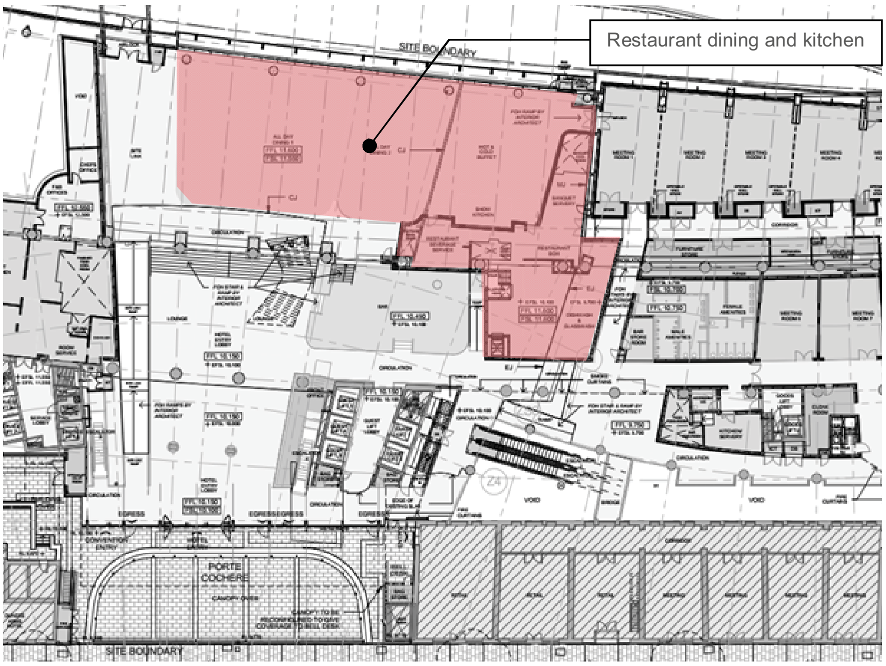


Figure 39 Class 6 restaurant and kitchen – ground floor

10.2 Intent of the BCA

10.2.1 Clause C1.1

The Guide to the BCA[36] states that the intent of clause C1.1 is 'to establish the minimum fire-resisting construction required for class 2-9 buildings.' The guide explains that 'the required type of construction of a building depends on risk levels as indicated by the class of building and the building's height as indicated by the rise in storeys.

The class of building is a measure of the building's likely:

- use;
- fire load;
- population; and
- mobility of the occupants, such as whether they are sleeping or alert.

The height (rise in storeys) of the building is relevant as a measure of likely evacuation times and evacuation difficulty.'

The guide also notes that other factors may need to be considered such as the maximum fire compartment size.

10.2.2 Clause C2.8

The Guide to the BCA states that the intent of clause C2.8 is 'to minimise the risk of a fire in one classification on a storey causing the failure of building elements in another classification on the same storey.'

The guide explains that 'the FRL required for building elements varies, depending on the expected fire load. This load is measured in the BCA by building classification. With these differing FRLs, it is important that a fire in one classification does not cause the failure of building elements in any other classification.

10.2.3 Clause C2.9

The Guide to the BCA states that the intent of clause C2.9 is 'to minimise the risk of a fire in one classification causing the failure of building elements in another classification in a different storey.'

The guide explains that 'the aim of C2.9 is for the fire load of a storey to determine the fire protection of the floor above it. A fire on one storey will affect the storey above to a greater degree than any storey below.'

10.3 Methodology

The assessment undertaken for the building was a quantitative absolute assessment involving the following sub-systems:

- Sub-system C – Fire spread and impact and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system F – Fire services intervention

10.4 Acceptance criteria

The acceptance criterion for this assessment is that the structure of the ground floor restaurant area can withstand the effects of a credible design fire scenario without failure. This will be achieved if the fire temperature is limited below the critical temperature for degradation of the structural elements. Alternatively, in the event of a fully developed flashover fire, the fire resistance level of the structure must exceed the equivalent fire severity.

[36] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

10.5 Fire hazards

The specific fire hazard associated with the reduced fire rating of the structure for the class 6 portion of the building is that a fire located in the all day dining restaurant and associated kitchen reaches sufficient size and produces sufficient temperatures to result in failure of the building elements.

The hazard associated with reduction in fire resistance of the restaurant and associated kitchen must be assessed in terms of the potential fire intensity and ability of the fire-rated construction to withstand the equivalent fire exposure.

The lower ground, ground and mezzanine level of the redeveloped building will be protected by a sprinkler system complying with the requirements of specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, the successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire[37,38,39].

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

CIBSE Guide E[40] notes the following potential concessions for buildings protected by sprinklers:

- Building compartment areas / volumes may be increased over that for a similar non-sprinklered building.
- A structural element is liable to maintain its load-bearing capacity, and that a separating element will maintain both its integrity and its ability to resist the transfer of heat. The fire resistance levels may therefore be reduced if sprinklers are fitted.

[37] England JP, Young SA, Hui MC and Kurban N, 2000, Guide for the design of fire resistant barriers and structures, Warrington Fire Research Australia and Building Control Commission, Melbourne VIC.
[38] Technical Memoranda TM19:1995 – Relationships for smoke control calculations, CIBSE, London UK.
[39] Lougheed GD, 1997, Expected size of shielded fires in sprinklered office buildings, ASHRAE Transactions, vol 103, pt 1, pp 395-410.
[40] CIBSE Guide E: Fire Engineering, 2010, 3rd edn, CIBSE, London, UK.

10.6 Fire scenarios

10.6.1 Selection of fire scenarios

The selection of appropriate fire scenarios is a critical element of any fire safety engineering assessment. The number of scenarios selected is dependent on the scope of the project and the method of assessment. The following factors must be taken into consideration when selecting credible design fire scenarios:

- likelihood of occurrence
- potential consequences
- impact on the issues being assessed.

Considering the criteria described above, the following credible design fire scenario has been selected to be analysed:

1. Sprinkler controlled fire in the ground floor restaurant
2. Sprinkler failure – fully developed fire in the ground floor restaurant
3. Sprinkler failure – fully development fire in the ground floor restaurant spreading to the adjoining hotel lobby

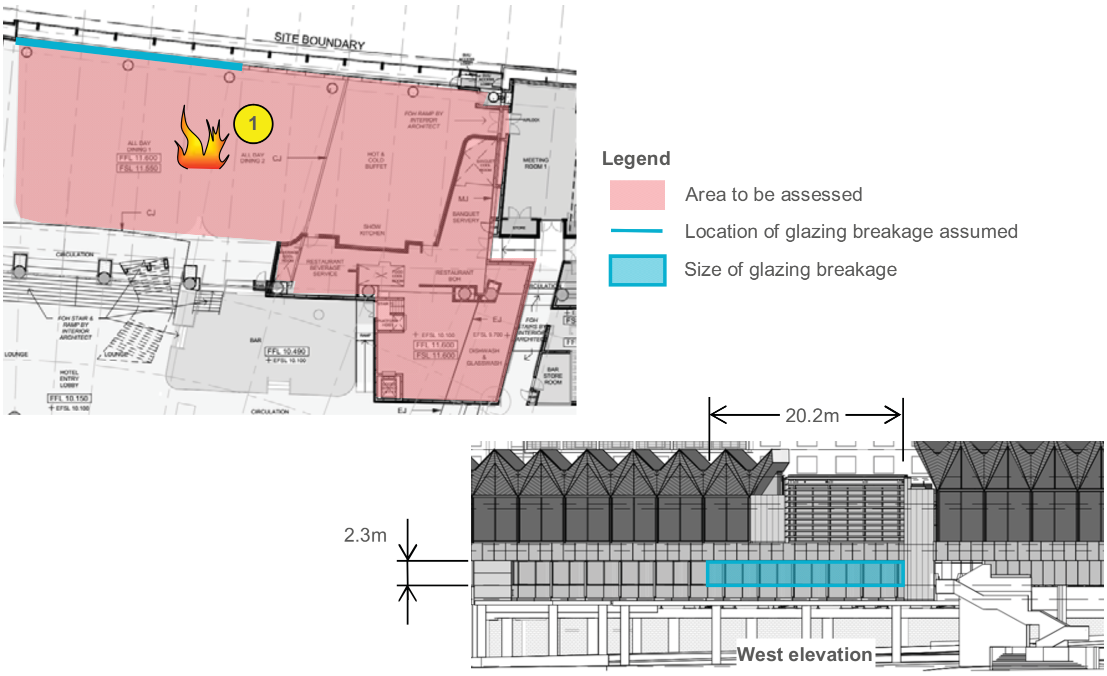


Figure 40 Fire scenario 2 – Ground floor, restaurant and kitchen (926m^2)

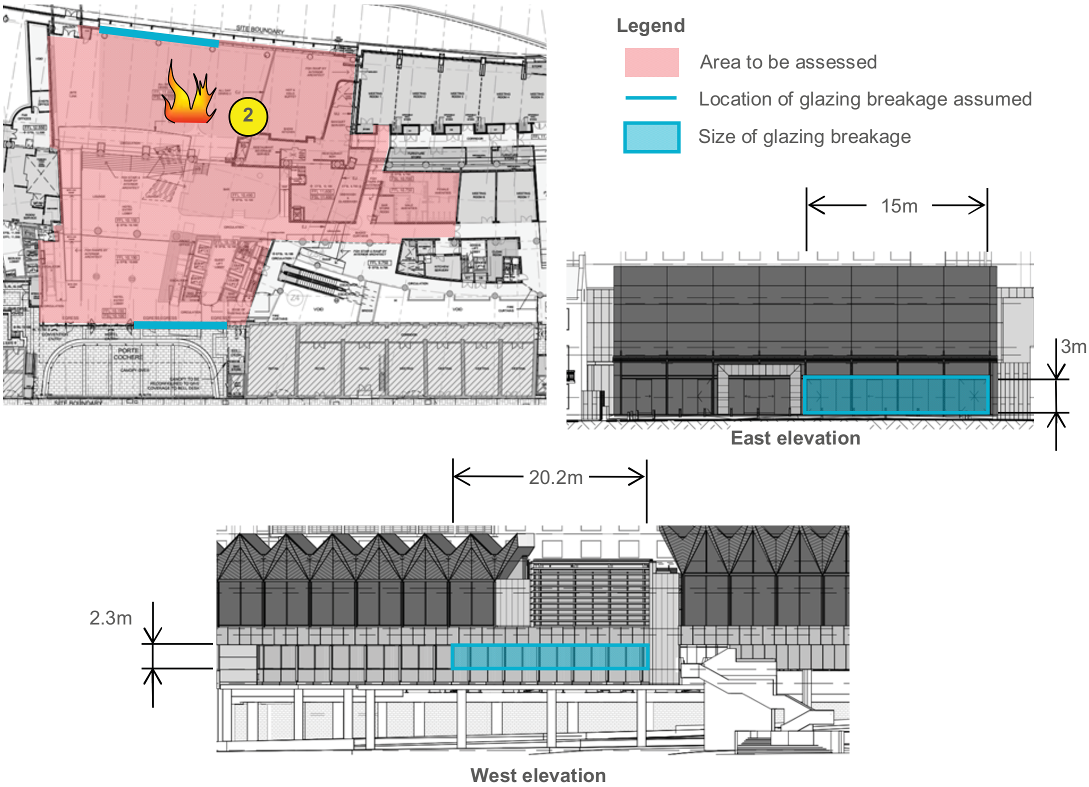


Figure 41 Fire scenario 3 – Ground floor, restaurant and main lobby (2550m^2)

10.6.2 Fire load

The duration of the heat exposure to the structure is related to the fire load within the building. Typical fire load densities can be obtained for the various parts of the building based on data collected during occupancy surveys. The fuel loads taken for the assessment are the 95% fractile fuel load as recommended in the IFEG[41]. The 95% fractile fuel load is reduced by 20% due to the combustion factor[42] in the assessment.

The use of the ground floor restaurant is not expected to vary over the life of the building. The fire load was based on an expected fire load for a restaurant determined on historical surveys[43] which is summarised in Table 22. The 95% fractile value was calculated based upon section 3.4.1 of the IFEG, using the upper multiplier of 2 for well-defined occupancies that are rather similar or with very limited differences in furniture and stored goods.

It should be noted that the average fire load in a restaurant is half that of a retail tenancy, both of which are classified as class 6 tenancies requiring the same FRLs under the DTS provisions of the BCA.

Occupancy	Average fire load (MJ/m²)	95% fractile fire load (with 20% reduction) (MJ/m²)
Retail	600	1040 (= 1300 × 0.8)
Canteen	300	480 (= 300 x 2 x 0.8)
Restaurant	300	480 (= 300 x 2 x 0.8)

Table 22 Typical fire loads

[41] International Fire Engineering Guidelines – Edition 2005, Australian Building Codes Board, Australia, p. 3.4-8.
[42] British Standard BS EN 1991-1-2:2002, Eurocode 1: Actions on Structures.
[43] International Fire Engineering Guidelines – Edition 2005, Australian Building Codes Board, Australia, Table 3.4.1a.

10.6.3 Performance of structure

The acceptance criterion for this assessment is based on demonstrating that the proposed loadbearing structural elements such as steel and reinforced concrete elements provide adequate resistance when exposed to fire conditions.

The design of steel reinforced structural elements under fire conditions is based on critical steel temperature concept. This is a comparison of the yield strength and loading at normal conditions and the yield strength and loading conditions in fire conditions.

The change in yield strength at elevated temperature has been experimentally investigated. An approximation of this test data has been included in many national standards such as AS 4100-1998 (structural steel) as shown in Figure 50.

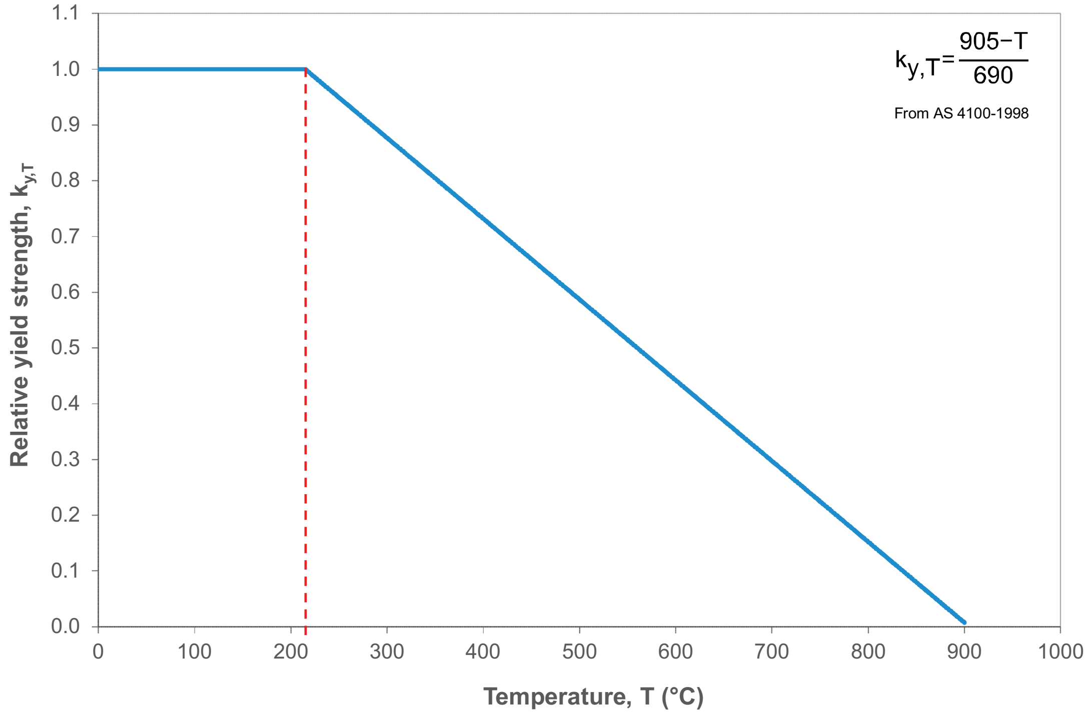


Figure 42 Design curves for reduction in yield strength of steel with temperature

The relationships show that the yield strength of structural steel when exposed to fire conditions does not reduce until the steel temperature reaches 215°C.

Reinforced concrete provides resistance to fire due to the thermal properties of the material. Concrete has a relatively low conductivity and high specific heat capacity, which is effectively increased by water retained within the material. The concrete cover over the reinforcement effectively provides protection for the steel within. The loadbearing capacity during fire of both steel and reinforced concrete elements can be determined by assessing the impact of elevated temperatures of the steel members or reinforcement within concrete elements[44]. This ignores the insulating effect of the concrete covering the reinforcement which is not expected to experience any significant spalling at low temperatures in sprinkler controlled fires.

[44] England JP, Young SA, Hui MC and Kurban N, 2000, Guide for the design of fire resistant barriers and structures, Warrington Fire Research Australia and Building Control Commission, Melbourne VIC.

Spalling damage to concrete – ie pieces breaking away from the surface – can occur at 250°C to 420°C if the concrete is rapidly heated by fire. At 300°C, strength loss starts however only the first few centimetres of concrete exposed to fire will get any hotter than this, with the temperature being well below this internally. At 550°C to 600°C, cement-based materials experience considerable creep and lose their loadbearing capacity. Above 600°C, concrete is not functioning at its full structural capacity[45]. Based upon these temperature-dependent characteristics of concrete, failure of concrete is unlikely if temperatures are maintained at or below 250°C.

10.7 Assessment

10.7.1 Scenario 1 – sprinkler controlled fire in the ground floor restaurant

The lower ground, ground and mezzanine level of the redeveloped building will be protected by a sprinkler system complying with the requirements of specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, it can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire[46,47,48].

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

The successful activation of the sprinkler system will limit the average compartment temperatures to below the critical temperatures for the structural elements in the building identified in 10.6.3. Consequently, the assessment demonstrates that the structure is capable of resisting the effects of a sprinkler controlled fire.

10.7.2 Scenarios 2 and 3 – sprinkler failure for a fire in the ground floor restaurant / main lobby

Determination of required FRL

To assess the impact of a sprinkler failure scenario in the building, the hazard associated with reduction in fire resistance of the ground floor restaurant must be assessed in terms of the potential fire intensity and ability of the fire-rated construction to withstand the equivalent fire exposure. Further detail of the analysis is provided in Appendix D.

Fire resistance calculations

A comparison of the proposed fire resistance level of the ground floor restaurant and the equivalent fire severity is summarised in Table 23 with the spreadsheet output included in Appendix D. The calculation indicates the proposed fire resistance level exceeds the equivalent fire severity for a fully developed fire.

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[45] Concrete and Fire, 2004, The Concrete Centre.
[46] England JP, Young SA, Hui MC and Kurban N, 2000, Guide for the design of fire resistant barriers and structures, Warrington Fire Research Australia and Building Control Commission, Melbourne VIC.
[47] Technical Memoranda TM19:1995 – Relationships for smoke control calculations, CIBSE, London UK.
[48] Lougheed GD, 1997, Expected size of shielded fires in sprinklered office buildings, ASHRAE Transactions, vol 103, pt 1, pp 395-410.

Scenario	Maximum equivalent fire severity (minutes)	Proposed FRL of structure (minutes)
Fire scenario 2 – ground floor – all day dining restaurant	81	120
Fire scenario 3 – ground floor – all day dining restaurant and main lobby	92	120

Table 23 Expected equivalent fire severity

10.7.3 Redundancy and safety factors

The assessment demonstrates that in the event of successful operation of the sprinkler system the fire temperatures are unlikely to exceed to the critical temperature for degradation of the structural elements.

As a redundancy, sprinkler failure scenarios involving fully developed flashover fires were assessed. The assessment demonstrates that an FRL of 120 minutes exceeds the equivalent fire severity. Due to the limited risk of sprinkler failure and the conservative fuel loads assumed, an additional safety factor has not been applied.

10.7.4 Fire brigade intervention

The proposed FRL of 120 minutes for the ground floor restaurant and kitchen is considered to provide adequate time for the fire brigade to commence firefighting to limit the fire severity and initiate search and rescue activities. Fire brigade are expected to initiate fire-fighting activities within approximately 30 minutes [49] – based on arrival time of 10 minutes and set-up within 20 minutes – for a building in Sydney. The three nearest fire stations attending to a potential incident at the hotel are as follows:

- The Rocks (166 Kent Street, The Rocks) located 1km from the site.
- City of Sydney (211-217 Castlereagh Street, Sydney) located 1.3km from the site.
- Pyrmont (147 Pyrmont Street, Pyrmont) located 1.4km from the site.

10.8 Conclusion

The assessment undertaken for the proposed design demonstrates that an FRL of 120/120/120 for the ground floor restaurant area provides an adequate level of fire resistance based upon the fire safety measures proposed and the expected fire severity within the building. It is therefore considered that the building achieves compliance with performance requirements CP1 and CP2 of the BCA, subject to compliance with the fire safety measures given in section 5.

[49] Fire Engineering Guidelines – 1st Edition, Fire Code Reform Centre Ltd, 1996, Table 13.1

11. Alternative solution 6 – Access to fire control room

11.1 Introduction

Clause E1.8 of the BCA states that a fire control centre facility must be provided in accordance with specification E1.8 for a building with an effective height of more than 25m.

Clause 8(b) of specification E1.8 of the BCA states that 'the fire control room must be accessible via two paths of travel –

i. one from the front entrance of the building; and

ii. one direct from a public place or fire isolated passageway which leads to a public place and has a door with an FRL of not less than -/120/30.'

The proposed fire control room is located at the northern end of the building and accessible from a single door directly adjacent to Sussex Street at the front entrance of the site as shown in Figure 43.

This assessment was undertaken to demonstrate that the design complies with performance requirement EP1.6 of the BCA.

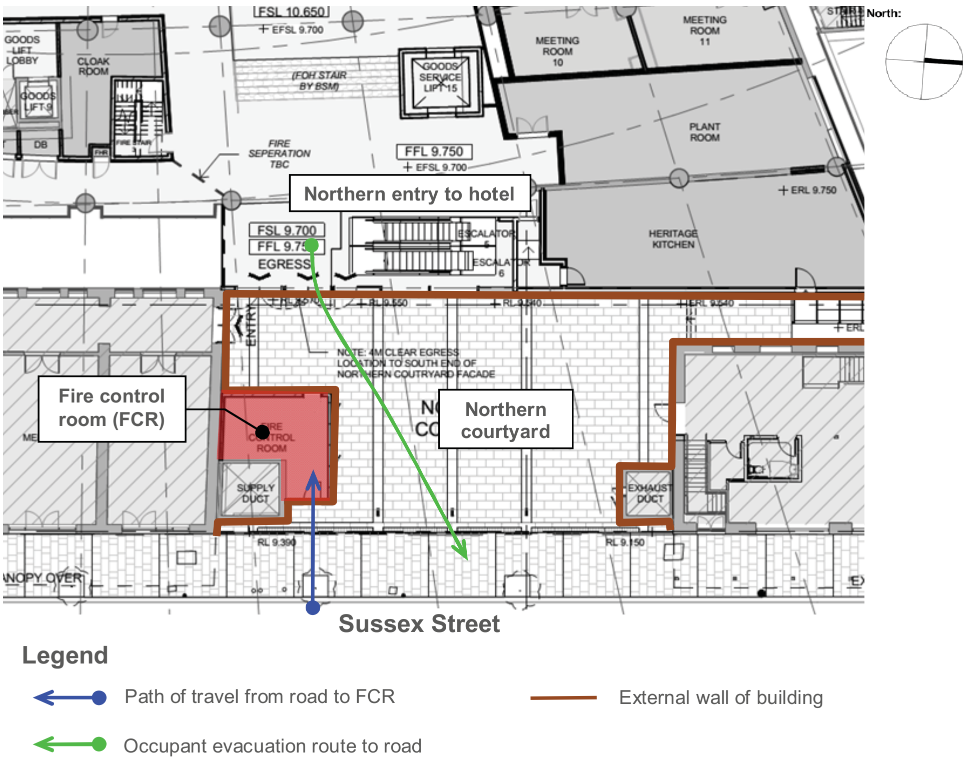


Figure 43 Path of travel to fire control room

11.2 Intent of the BCA

The Guide to the BCA[50] states that the intent of clause 8 of specification E1.8 is 'to require adequate access to a fire control room.' The guide states that 'since it will be necessary for the fire brigade to gain access to the fire control room while the building is being evacuated, access to it must not be obstructed by people evacuating. Providing access by way of two paths of travel is to help fire brigade access. One of those paths must be from the front entrance of the building, and the other must be from a public place or fire isolated passage which leads from a public place.'

[50] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

11.3 Methodology

The assessment undertaken for the building was a qualitative absolute assessment involving sub-system F – Fire services intervention.

11.4 Acceptance criteria

The acceptance criterion for the assessment is to demonstrate that fire brigade access into the fire control room is adequately facilitated with a single entry point.

11.5 Fire hazards

The specific issue being considered in this assessment is the access to the fire control room from a single access door directly adjacent to the road, in lieu of a second, alternative access door.

The single access door to the fire control is directly adjacent to the footpath and Sussex Street. In the event of a fire within the hotel building, some occupants are expected to evacuate via the northern courtyard adjacent to the fire control room. The fire hazard to be assessed is the risk of occupants blocking or impeding fire brigade entry into the fire control room via the single access door.

11.6 Assessment

The intent of requiring two accessible paths of travel to the fire control room is to ensure fire brigade personnel are able to reach the room to coordinate firefighting activities without being blocked by a fire or occupants evacuating from the building.

The proposed fire control room is located external to the main hotel building adjacent to an open courtyard which is directly accessible from Sussex Street as shown in Figure 43. Entry into the fire control room is via a single doorway located 1.5m away from – and directly facing – the footpath on Sussex Street. Therefore, fire brigade attending can park the appliance directly outside the fire control room and readily identify and walk to the single access door.

The path of travel from Sussex Street to the fire control room access door would not be impeded by occupants evacuating from the main hotel via the northern courtyard as occupants are not required to walk past the door. In addition, the northern courtyard is considered sufficiently wide – approximately 15m at the narrowest point – for occupants evacuating to remain clear of the fire control room and not impede fire brigade operations.

Furthermore, it is understood that the requirement by the BCA for a second, alternative access door to a fire control room is generally applicable to fire control rooms which are located within a building and not external to the building. The proposed fire control room is external to the building. The provision of a second, alternative access door is not considered to provide any additional benefit with respect to access into the fire control room as these doors would need to be accessed from the same northern courtyard.

11.7 Conclusion

The assessment demonstrates that the proposed fire control room which is accessible from a single door directly adjacent to Sussex Street adequately facilitates fire brigade access and is therefore considered to achieve compliance with performance requirement EP1.6 of the BCA, subject to compliance with the fire safety measures given in section 5.

12. Alternative solution 7 – Discharge location of fire stair 3

12.1 Introduction

Clause D1.7(b) of the BCA states that each fire isolated stairway 'must provide independent egress from each storey served and discharge directly, or by way of its own fire isolated passageway –

(i) to a road or open space; or

(ii) to a point –

- (A) in a storey or space, within the confines of the building, that is used only for pedestrian movement, car parking or the like and is open for at least 2/3 of its perimeter; and
- (B) from which an unimpeded path of travel, not further than 20m is available to a road or open space; or

(iii) into a covered area that –

- (A) adjoins a road or open space; and
- (B) is open for at least 1/3 of its perimeter; and
- (C) has an unobstructed clear height throughout, including the perimeter of openings, of not less than 3m; and
- (D) provides an unimpeded path of travel from the point of discharge to the road or open space of not more than 6m.

The existing fire isolated stair 3 serves the mezzanine floor and levels 1 to 10 of the existing northern portion of the hotel. The stair is proposed to be modified to discharge into the northern ground floor lobby which is within the confines of the building and approximately 10m to the open space of the northern courtyard as shown in Figure 44.

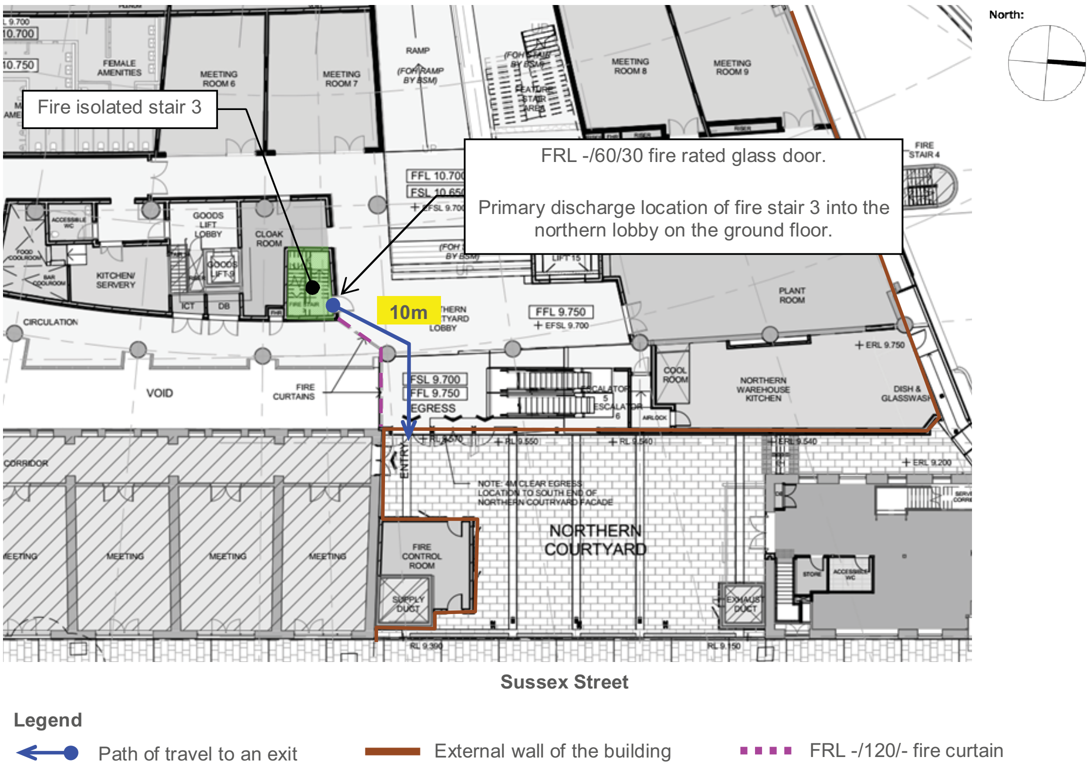


Figure 44 Primary discharge location of fire isolated stair 3 on the ground floor

An alternative discharge location is also provided on the lower ground floor into the covered bus parking bay area adjacent to Slip Street as shown in Figure 45. The bus parking bay area is not open for at least 1/3 of its perimeter and is further than 6m from the point of discharge to open space.

This assessment was undertaken to demonstrate that the design complies with performance requirements CP2, DP4, DP5 and EP2.2 of the BCA.

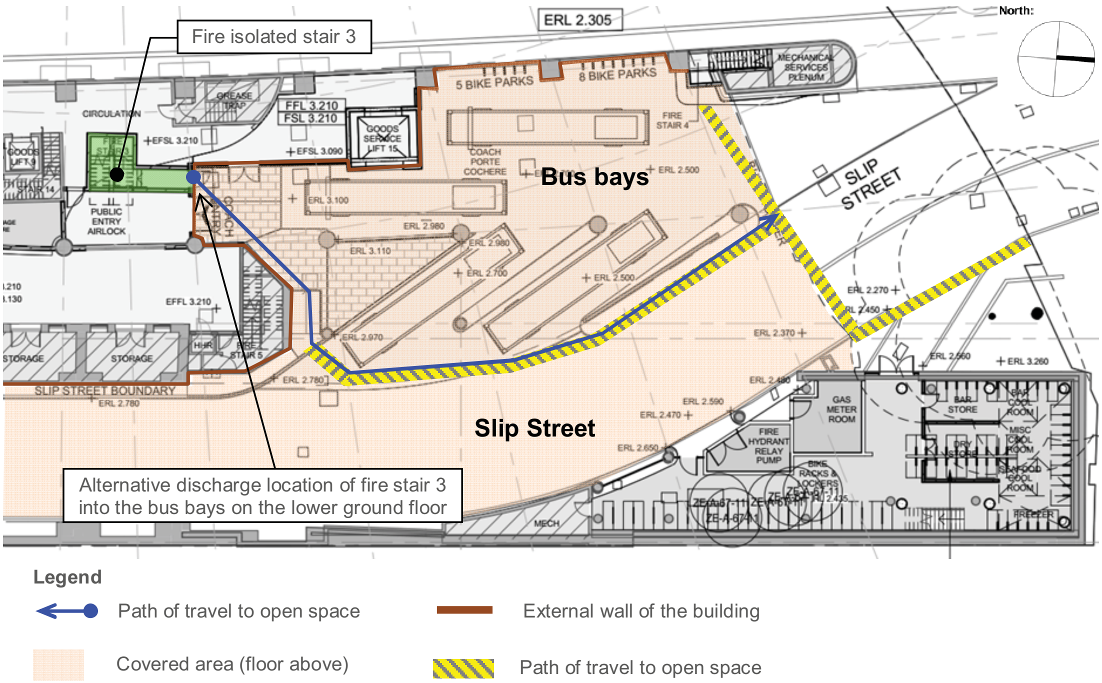


Figure 45 Alternative discharge location of fire isolated stair 3 on the lower ground floor

12.2 Intent of the BCA

12.2.1 Specification C1.1

The Guide to the BCA[51] states that the intent of clause 3.1 of specification C1.1 is 'to specify the FRL and other requirements for building elements in type A construction'.

12.2.2 Clause C3.8

The Guide to the BCA states that the intent of clause C3.8 of the BCA is 'to maintain the integrity of a fire isolated exit and to protect people using fire isolated exits by providing adequately protected door and window openings'.

12.2.3 Clause D1.7

The Guide to the BCA states that the intent of clause D1.7 is 'to enable occupants to safely enter a fire isolated exit which discharges to a safe location.' The guide expands further and states that 'D1.7(b)(i) requires fire isolated exits to discharge to roads or open spaces. However there are some exemptions:

- D1.7(b)(ii) sets out the requirements for a fire isolated exit to discharge into an area within a building (including the requirement that it be open for at least two thirds of its perimeter, to aid smoke ventilation); and

[51] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

- D1.7(b)(iii) sets out the requirements for a fire isolated exit to discharge into a covered area outside the building (including the requirement that it be open for at least one thirds of its perimeter, to aid smoke ventilation).'

12.3 Methodology

The assessment undertaken for the building was a qualitative absolute assessment involving the following sub-systems:

- Sub-system B – Smoke development and spread and control
- Sub-system C – Fire spread and impact and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control

12.4 Acceptance criteria

The acceptance criterion for this assessment is to demonstrate the discharge location of fire isolated stair 3 adequately facilitates safe occupant evacuation to a road or open space.

12.5 Fire hazards

12.5.1 Layout and fire load

Fire isolated stair 3 complies with the DTS requirements of the BCA with the exception that the final exit discharge door is located within the confines of the building, approximately 10m to open space on the ground floor. The discharge location is into the northern hotel lobby, adjacent to the entry and exit doors to the northern courtyard.

The hazard associated with the discharge location of fire isolated stair 3 within the building is the potential risk of a fire occurring within the northern lobby adjacent to the discharge location, creating untenable conditions and blocking the exit. The immediate area is a primary circulation space where people enter and exit the hotel and congregate prior to meetings. It is inherently a low fire load area.

An alternative discharge location from the stair is provided on the lower ground floor into the Slip Street bus parking bays. This is provided to enable occupants to exit the stair and building safely in the event of a fire in the northern lobby.

12.5.2 Sprinkler protection

The lower ground, ground and mezzanine level of the redeveloped building will be protected by a sprinkler system complying with the requirements of specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, the successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire.

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

12.6 Assessment

12.6.1 Fire on the ground floor – northern lobby

Fire load

As discussed in section 12.5.1, the immediate area around the discharge location of stair 3 on the ground floor is a circulation space where people enter and exit the hotel.

Fire isolated stair 3 complies with the DTS requirements of the BCA with the exception that the final exit discharge door is located within the confines of the building, approximately 10m to open space. The discharge location is into the northern hotel lobby which connects directly to the northern entry and exit doors of the building to the external courtyard.

The northern hotel lobby is a primary circulation route to the meeting rooms within the hotel and is inherently a low fire load area. The risk of a fire occurring within the northern lobby is considered to be minimal.

Fire separation

The discharge door on the ground floor is proposed to be a -/60/30 fire rated clear glass door which complies with the requirements of clause C3.8 of the BCA. The fire separation is expected to limit fire and smoke spread into the stair.

Exit blocked scenario

The stair is provided with a door on the ground floor and a door on the lower ground floor serving as alternative discharge locations to a road or open space as shown in Figure 44 and Figure 45. The alternative discharge locations are in different fire compartments and lead to different routes to a road or open space.

In the event that a fire occurs in the northern lobby, or one of the adjoining meeting rooms, there is a risk that the exit door at the discharge location from stair 3 on the ground floor could be blocked. Occupants using fire stair 3 would be able to see and recognise – through the glass door – that the discharge location is blocked and then proceed down the stairs to the alternative discharge location from the stair and evacuate safely via the lower ground floor exit at the Slip Street bus bays. From the discharge location on the lower ground floor, occupants can travel via the marked, designated pathway to open space.

Wayfinding

Signage is proposed to be provided inside the stair adjacent to the glazed fire door on the ground floor. The signage will have an arrow pictorial and state ‘Exit on this level. If this exit is blocked by fire or smoke, continue down the stair to alternative exit.’ In the event that occupants see – via the glazed fire door – that the exit door they are standing at is blocked by smoke or fire, the signage is expected to direct occupants to the alternative exit available on the lower ground floor.

12.6.2 Fire on the lower ground floor – Slip Street bus bays

A fire within the Slip Street bus bay area, adjacent to the discharge location of fire stair 3 on the lower ground floor is not expected to affect occupants utilising the stair to evacuate the building. The primary discharge location of the stair is on the ground floor and as discussed in section 12.6.2, signage is provided within the stair to advise occupants to evacuate at the ground level.

Upon exiting the stair on the ground floor, occupants will be within the northern lobby from which the distance to the nearest exits into the northern courtyard is approximately 10m. An illuminated, directional exit sign opposite the discharge location is provided to direct occupants to these exits.

12.7 Conclusion

The assessment demonstrates that primary and alternative discharge locations of fire isolated stair 3, in conjunction with the sprinkler system within the building, adequately facilitates occupant evacuation to open space. The proposed design of the building is therefore considered to achieve compliance with performance requirements CP2, DP4, DP5 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

13. Alternative solution 8 – Discharge location of fire stair 2

13.1 Introduction

Clause D1.7(b) of the BCA states that each fire isolated stairway 'must provide independent egress from each storey served and discharge directly, or by way of its own fire isolated passageway –

(i) to a road or open space; or

(ii) to a point –

- (A) in a storey or space, within the confines of the building, that is used only for pedestrian movement, car parking or the like and is open for at least 2/3 of its perimeter; and
- (B) from which an unimpeded path of travel, not further than 20m is available to a road or open space; or

(iii) into a covered area that –

- (A) adjoins a road or open space; and
- (B) is open for at least 1/3 of its perimeter; and
- (C) has an unobstructed clear height throughout, including the perimeter of openings, of not less than 3m; and
- (D) provides an unimpeded path of travel from the point of discharge to the road or open space of not more than 6m.

Specification C1.1 of the BCA requires that a fire isolated stair serving a class 9 part of a building achieve an FRL of not less than -/120/120 where non loadbearing. Clause C3.8 of the BCA requires that openings in fire isolated stair shafts are protected by self-closing or automatically closing fire doors achieving an FRL of not less than -/60/30.

The existing fire isolated stair 2 serves the mezzanine floor and levels 1 to 15 of the existing southern portion of the hotel. The stair is proposed to be modified to discharge into the main, southern ground floor lobby which is within the confines of the building as shown in Figure 46.

Automatic fire curtains with an FRL of -/60/- will be provided to protect the path of travel between the stair discharge location and the final exit door to the open space of the porte cochere. The area separated by the fire curtain is approximately 3.6m long and will essentially form an extension of the fire isolated exit when closed.

The DTS provisions for protection of openings in fire isolated exits do not recognise fire curtains as an acceptable method of protection. Additionally, the proposed curtains will not achieve the integrity and insulation criteria of 120 minutes for a fire isolated stair or 30 minutes insulation for a doorway in a fire isolated exit.

This assessment was undertaken to demonstrate that the design complies with performance requirements CP2, DP4, DP5 and EP2.2 of the BCA.

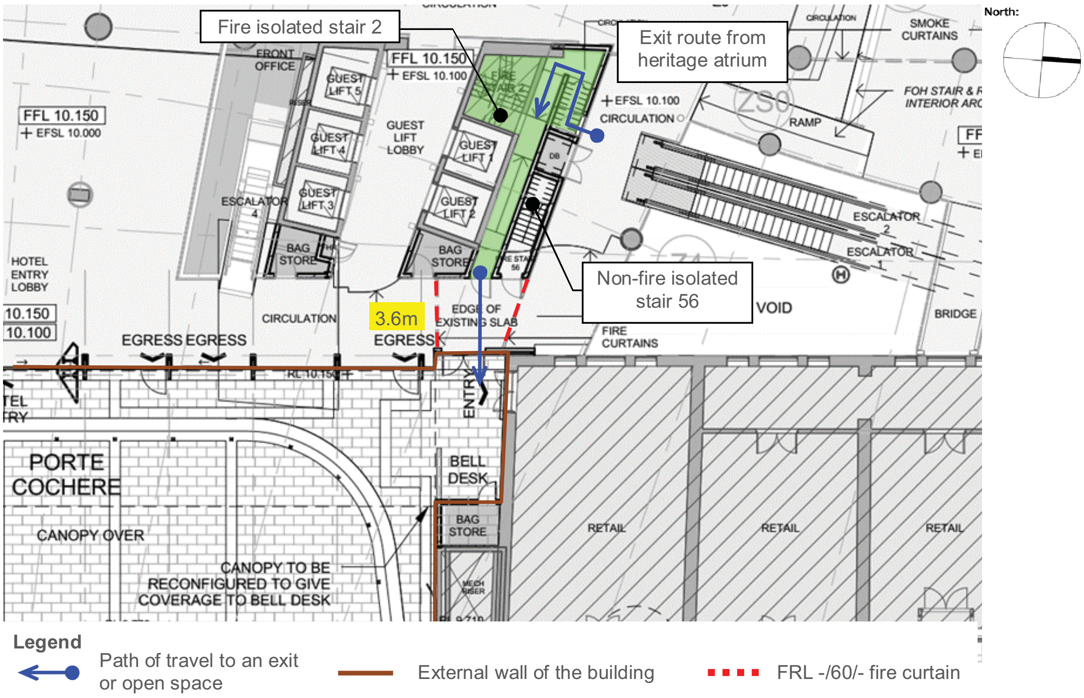


Figure 46 Discharge of fire isolated stair 2

13.2 Intent of the BCA

13.2.1 Specification C1.1

The Guide to the BCA[52] states that the intent of clause 3.1 of specification C1.1 is ‘to specify the FRL and other requirements for building elements in type A construction’.

13.2.2 Clause C3.8

The Guide to the BCA states that the intent of clause C3.8 of the BCA is ‘to maintain the integrity of a fire isolated exit and to protect people using fire isolated exits by providing adequately protected door and window openings’.

13.2.3 Clause D1.7

The Guide to the BCA states that the intent of clause D1.7 is ‘to enable occupants to safely enter a fire isolated exit which discharges to a safe location.’ The guide expands further and states that ‘D1.7(b)(i) requires fire isolated exits to discharge to roads or open spaces. However there are some exemptions:

- D1.7(b)(ii) sets out the requirements for a fire isolated exit to discharge into an area within a building (including the requirement that it be open for at least two thirds of its perimeter, to aid smoke ventilation); and
- D1.7(b)(iii) sets out the requirements for a fire isolated exit to discharge into a covered area outside the building (including the requirement that it be open for at least one thirds of its perimeter, to aid smoke ventilation).’

[52] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

13.3 Methodology

The assessment undertaken for the building was a qualitative absolute assessment involving the following sub-systems:

- Sub-system B – Smoke development and spread and control
- Sub-system C – Fire spread and impact and control
- Sub-system D – Fire detection, warning and suppression
- Sub-system E – Occupant evacuation and control

13.4 Acceptance criteria

The acceptance criterion for this assessment is to demonstrate the discharge location of fire isolated stair 2 adequately facilitates safe occupant evacuation to a road or open space.

13.5 Fire hazards

13.5.1 Layout and fire load

Fire isolated stair 2 complies with the DTS requirements of the BCA with the exception that the final exit discharge door is located within the confines of the building, approximately 3.6m to open space. The discharge location is into the front portion of the main hotel lobby, directly adjacent to the entry and exit doors of the building.

The hazard associated with the discharge location of fire isolated stair 2 within the building is the potential risk of a fire occurring adjacent to the discharge location and blocking the exit. The immediate area is a primary circulation route where people enter and exit the hotel and is inherently a low fire load area. The risk of combustible items being located directly against the fire curtains or obstructing the operation of the curtain is considered to be minimal.

13.5.2 Sprinkler protection

The lower ground, ground and mezzanine level of the redeveloped building will be protected by a sprinkler system complying with the requirements of specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, the successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire.

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

13.6 Assessment

13.6.1 Automatic fire curtain

Fire separation

The discharge location of the fire isolated stair is proposed to be fire separated from the remainder of the lobby by automatic fire curtains achieving an FRL of -/60/-. The curtain will deploy upon activation of a fire alarm or sprinkler activation within the lower ground or ground floors creating a fire separated passage to protect occupants discharging from the stair to the final exit door leading to the open space of the porte cochere. The curtain will gravity fail safe to the closed position in the event of power failure.

Maintenance requirements

The fire curtains are required to be listed as a critical fire safety measure and maintained on a minimum 6-montly basis by trained and competent technicians. Furthermore, manual deployment via smoke detection and switch at the control panel, as well as testing of the fail-safe closing mechanism under power failure is required to be undertaken every 3 months. Strict adherence to the maintenance and testing regime is expected to minimise the likelihood of the fire curtains failing to deploy and improve their reliability.

Fire curtain failure

In considering a scenario where a fire curtain fails to deploy to the closed position, only one of the two fire curtains separating the discharge location is expected to fail at a given time.

As discussed in section 13.5.1, the vicinity of the discharge location is a primary circulation route where people enter and exit the hotel and is inherently a low fire load area. The likelihood of a fire occurring in this space is considered to be low to nil.

The nearest fire which may occur is in the adjacent bag store. The bag store is enclosed with construction achieving an FRL of 60/60/60 and the door opening into the bag store is a -/60/30 self-closing fire door which is expected to contain a fire occurring within this space. Some smoke may leak into the circulation space and the discharge location of fire stair 2, however occupants would only need to travel a short distance of 3.6m to exit the building. Given this short distance and the clear line of sight to the exit, along with the illuminated exit sign above the exit door, occupants are not expected to have difficulty in locating the exit and evacuate from the building.

In addition, the ground floor is provided with a smoke exhaust system and expected to create a negative pressure to minimise the spread of smoke into the discharge location in the event of a fire curtain failure scenario.

13.6.2 Integrity

Integrity is the ability of a material or assembly to resist the passage of flames and hot gases. The proposed automatic fire curtains will achieve an integrity rating of 60 minutes. Although this is less than the 120 minutes required for the walls of a fire isolated passage, it is equivalent to the 60 minute integrity rating required for a doorway into a fire isolated exit.

The BCA requires fire doors into fire isolated stairs and passages to achieve an integrity rating of 60 minutes acknowledging the low fire hazard associated with circulation areas directly adjacent to doorways. It is considered reasonable to apply the same logic to the automatic fire curtain considering that the area adjacent is also circulation / lobby space with limited fire load. On this basis, the integrity performance of the curtain of 60 minutes is considered to be equivalent.

13.6.3 Insulation

Insulation is the ability of an assembly to maintain a temperature on the surface not exposed to the fire. According to AS 1530.4-2005, a building element fails the insulation criterion if the average temperature of the unexposed face of the test specimen rises by more than 140K above the initial temperature. It also fails if the temperature at any location on the unexposed face of the test specimen rises by more than 180K above the initial temperature.

The FRL criterion for insulation is intended to prevent the ignition of combustible items on the non fire affected side of a partition which may be in direct contact with the partition – eg a fire curtain. Objects in direct contact with the fire curtain can be heated via conduction. The criteria in AS 1530.4-2005 for failure of the insulation component are intended to represent temperatures which could cause piloted ignition of combustibles in contact with the fire rated element.

This is demonstrated by a range of piloted and spontaneously ignition temperatures for various materials listed in Table 24.

Material	Piloted ignition temperature (°C)	Spontaneous ignition temperature (°C)
Paper [53]	224	224
Cotton [53]	230-270	250
Wood [54]	300-410	600
Thermoplastics [53]	296-442	394-520
Thermosetting plastics [53]	341-541	422-606

Table 24 Ignition temperatures

As the fire curtains achieve an integrity rating of 60 minutes, it is considered that ignition of combustibles would more likely be non-piloted or spontaneous. Considering that the area which is being fire separated by the fire curtains is used as a circulation / lobby space, the risk of combustibles in direct contact with the fire curtains is expected to be low.

As discussed in section 13.5.2, compartment temperatures outside of the immediate area of fire origin can be expected to be less than 100°C in the event of successful sprinkler operation. A high degree of energy created from the heat of the fire is removed when the water from the sprinklers vaporise and as such the temperature of the fire curtains is reduced. On this basis the acceptance criteria for insulation – ie a rise in temperature of 140K – is not expected to be exceeded in the event of a sprinkler controlled fire.

13.6.4 Smoke spread and stair pressurisation

As the fire curtain represents a non-standard method of protection for the fire isolated exit, the risk of smoke spread into the exit must also be evaluated. The existing stair is provided with a pressurisation system in accordance with Ordinance 70. The performance of the system is to be maintained accounting for the proposed modifications to the discharge location.

In order to mitigate the risk of smoke spread into the passage formed by the fire curtains in the event of a fire in the adjacent lobby, the curtain is to be fitted with perimeter smoke seals on both vertical edges of the track.

13.7 Conclusion

The assessment demonstrates that discharge location of fire isolated stair 2, in conjunction with the automatic fire curtains provided, adequately facilitates occupant evacuation to open space. The proposed design of the building is therefore considered to achieve compliance with performance requirements CP2, DP4, DP5 and EP2.2 of the BCA, subject to compliance with the fire safety measures given in section 5.

[53] Babrauska, V, 2003, Ignition Handbook, Fire Science Publisher, USA, pp241, 1067.
[54] Drysdale, D, 1999, An Introduction to Fire Dynamics, John Wiley & Sons, England, pp227.

14. Alternative solution 9 – Convention roof truss structure

14.1 Introduction

The steel roof trusses forming the roof structure of the northern and southern convention rooms on the mezzanine floor are not proposed to be fire rated as shown in Figure 47. The roof trusses have been considered as internal loadbearing trusses requiring a FRL of 120/-/-. The columns and beams supporting the roof trusses are proposed to be fire rated in accordance with specification C1.1 of the BCA.

This assessment was undertaken to demonstrate that the design complies with performance requirement CP1 of the BCA.

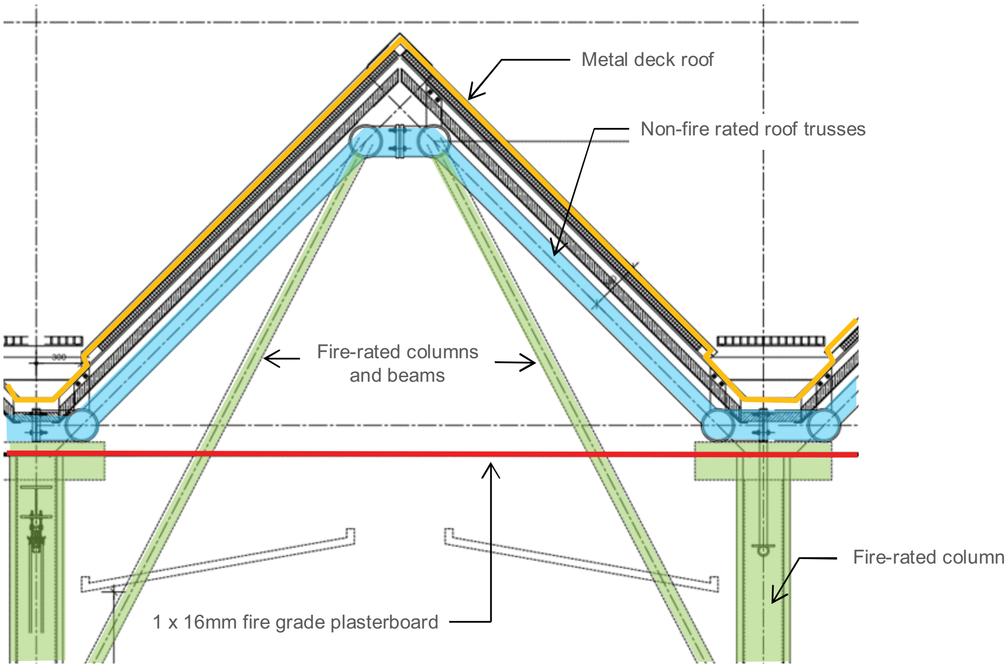


Figure 47 Internal section of convention roof

14.2 Intent of the BCA

The Guide to the BCA[55] states that the intent of clause 3.1 of specification C1.1 is ‘to specify the FRL and other requirements for building elements in type A construction’.

Clause 3.5 of specification C1.1 of the BCA provides a concession and states that a roof need not comply with table 3 of the specification if its covering is non-combustible and the building has a sprinkler system complying with specification E1.5 installed throughout.

The Guide to the BCA states that the intent of the concession given by clause C3.5 is ‘to allow roofs of certain buildings not to have a fire-resistance level (FRL).’ It further states that ‘clause 3.5 grants a number of concessions by which certain roofs need not have an FRL, provided the roof covering is non-combustible. In clause C3.5(a), the BCA assumes that the specified sprinkler system will control any fire prior to it breaking through the roof.’

14.3 Methodology

The assessment undertaken for the building was a qualitative absolute assessment involving sub-system C – Fire spread and impact and control.

[55] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

14.4 Acceptance criteria

The acceptance criteria for the assessment is to demonstrate that the roof structure can withstand the effects of a credible design fire scenario without failure. This will be achieved if the fire temperature is limited below the critical temperature for degradation of the structural elements.

14.5 Fire hazards

The fire hazard associated with the non fire-rated roof trusses is the risk of collapse of the roof in the event of a fire with the convention rooms.

14.6 Assessment

14.6.1 Performance of structure

The acceptance criterion for this assessment is based on demonstrating that the proposed loadbearing structural elements such as steel provide adequate resistance when exposed to fire conditions.

The design of steel reinforced structural elements under fire conditions is based on critical steel temperature concept. This is a comparison of the yield strength and loading at normal conditions and the yield strength and loading conditions in fire conditions.

The change in yield strength at elevated temperature has been experimentally investigated. An approximation of this test data has been included in many national standards such as AS 4100-1998 (structural steel) as shown in Figure 50.

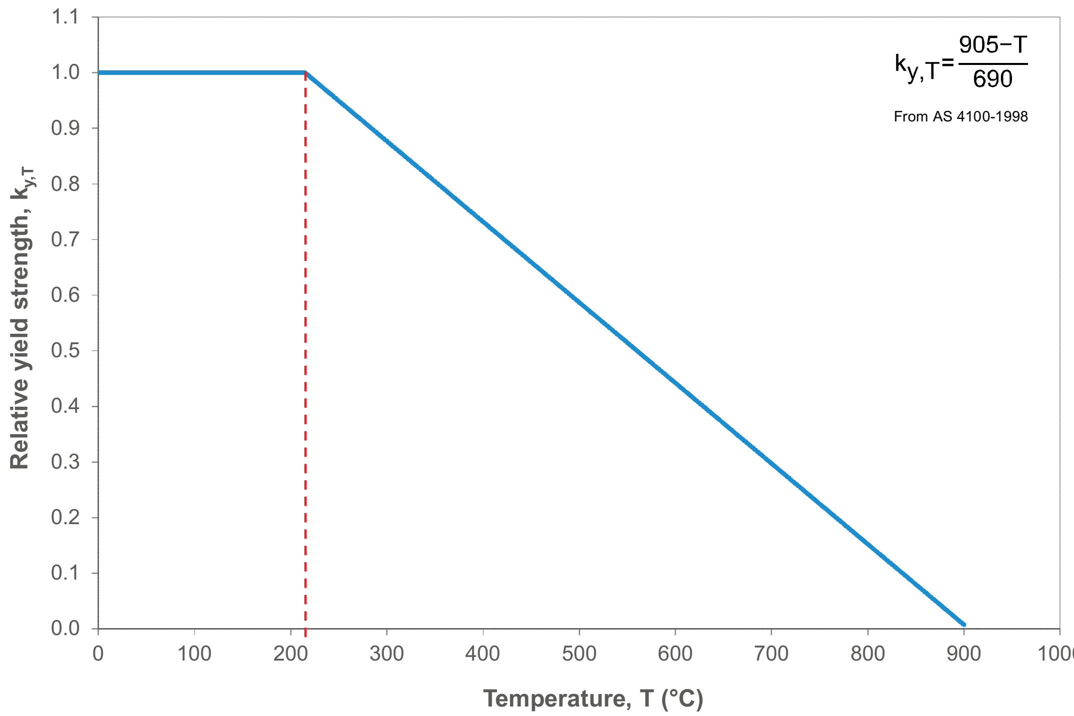


Figure 48 Design curves for reduction in yield strength of steel with temperature

The relationships show that the yield strength of structural steel when exposed to fire conditions does not reduce until the steel temperature reaches 215°C.

14.6.2 Impact of sprinklers

The lower ground, ground and mezzanine level of the redeveloped building is proposed to be provided with a sprinkler system in accordance with specification E1.5 of the BCA and AS 2118.1-1999. The remainder of the existing hotel building is also provided with a sprinkler system complying with AS 2118-1982. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, the successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire.

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

The successful activation of the sprinkler system will limit the average compartment temperatures to below the critical temperatures for the steel roof trusses. Consequently, the assessment demonstrates that the structure is capable of resisting the effects of a sprinkler controlled fire.

14.6.3 Impact of sprinkler failure

In the event of the sprinklers failure to operate, adequate redundancy is considered to be provided within the proposed design.

Whilst the roof trusses are not fire rated, a ceiling is provided below the convention room. The ceiling is proposed to be constructed of 16mm fire grade plasterboard which is considered to perform as a fire-protective covering. It is noted that 13mm fire-protective grade plasterboard satisfies the requirements of a ‘fire-protective covering as defined under clause A1.1 of the BCA. With respect to fire-protective coverings, the Guide to the BCA states that ‘while not fire rated, these elements have been found to provide nominal protection from the spread of fire of at least 20-30 minutes.

In addition, the roof trusses are located 6.9m above the floor level of the convention rooms at the lowest point. Therefore, the roof trusses are unlikely to be exposed directly to a fire occurring on the floor. Whilst there are speakers, projectors and acoustic panels located below the ceiling which may burn, they are considered unlikely to result in a significant fire which would impact on the inherent structural strength of the roof trusses.

14.6.4 Comparison to design complying with the BCA

Clause 3.5 of specification C1.1 of the BCA provides a concession and states that a roof need not comply with table 3 of the specification if its covering is non-combustible and the building has a sprinkler system complying with specification E1.5 installed throughout.

The proposed roof covering is comprised of metal deck panels which are non-combustible and the lower ground, ground and mezzanine floor of the building are provided with a sprinkler system complying with specification E1.5 throughout. The remainder of the building is also provided with a sprinkler system complying with AS 2118-1982 which does not impact on the roof of the new convention rooms.

The proposed design is therefore considered to be similar to a DTS-complying design with the exception that the roof trusses supporting the roof covering are not fire-rated.

The structural engineer has confirmed that failure of one or two of the roof trusses may lead to local failure of the roof structure and in the worst case scenario, failure of multiple roof trusses may lead to collapse of the roof itself. However, this would not lead to progressive collapse of the remainder of the building. This same scenario could occur in a DTS-complying design.

14.7 Conclusion

The assessment demonstrates that the steel roof structure can withstand the effects of a credible design fire scenario without failure. The proposed design of the building is therefore considered to achieve compliance with performance requirement CP1 of the BCA, subject to compliance with the fire safety measures given in section 5.

15. Alternative solution 10 – Wharf Lane bridge structure

15.1 Introduction

Clause C1.1 and specification C1.1 of the BCA requires loadbearing internal columns and floors to achieve an FRL of 120/-/- and 120/120/120 respectively in a class 9b building of type A construction,

The Wharf Lane bridge connects the commercial foyer of the new tower and Sussex Street as shown in Figure 49. The bridge is proposed to be constructed with a non-fire rated structure comprising steel frames, beams and rafters supporting timber joists and timber floor boarding.

This assessment was undertaken to demonstrate that the design complies with performance requirements CP1 and DP4 of the BCA.

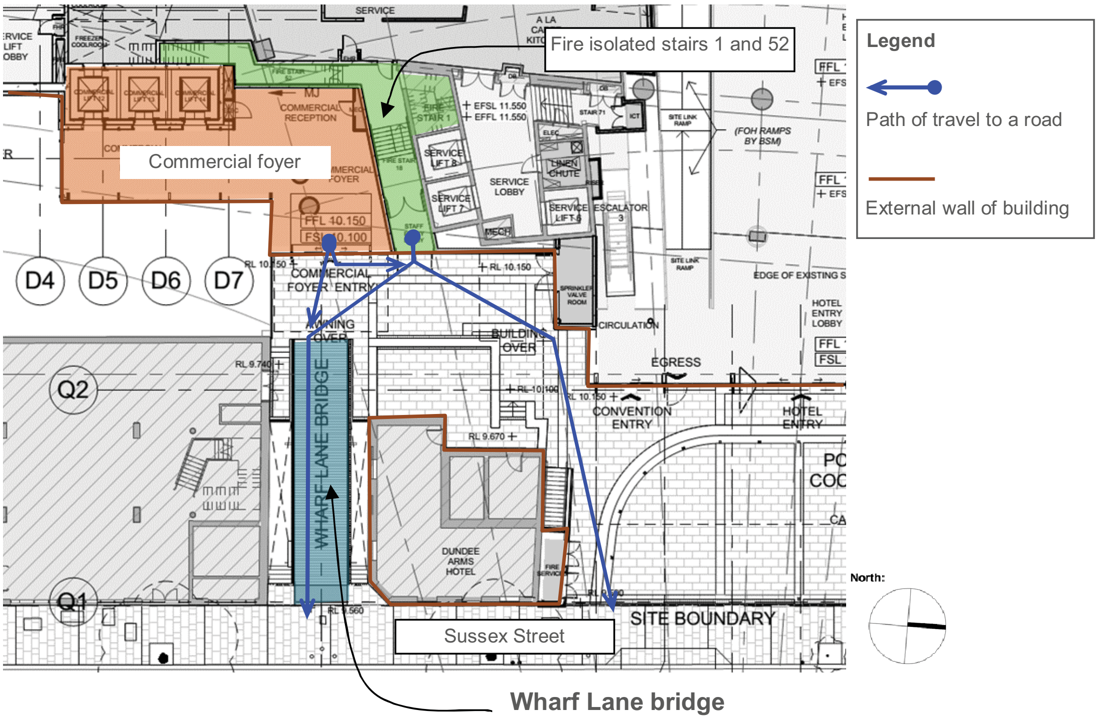


Figure 49 Wharf Lane bridge

15.2 Intent of the BCA

The Guide to the BCA[56] states that the intent of clause 3.1 of specification C1.1 is ‘to specify the FRL and other requirements for building elements in type A construction’.

15.3 Methodology

The assessment undertaken for the building was a qualitative absolute assessment involving the following sub-systems:

- Sub-system C – Fire spread and impact and control
- Sub-system E – Occupant evacuation and control

[56] National Construction Code Series 2013, Volume One – Building Code of Australia – Guide, Australian Building Codes Board, Australia.

15.4 Acceptance criteria

The acceptance criterion for this assessment is to demonstrate that the non fire-rated bridge structure does not adversely impact occupants beneath the bridge in the event of a fire located there. In addition, it is to be demonstrated that failure of the bridge structure does not adversely impact upon occupants evacuating from the hotel building or commercial lobby.

15.5 Fire hazards

15.5.1 Fire load

The primary fire hazard with respect to the risk to the bridge structure is the size and intensity of a potential fire in the undercroft. The undercroft is a back of house staff area connected to the Dundee Arms building, however it is not intended to be used as a storage space due to its visual presence below the Wharf Lane bridge which acts as a primary entry to the commercial tower

15.5.2 Low population

The undercroft is not expected to be frequently used or occupied by people on a regular basis. When occupied, the number of occupants at any one time is expected to be limited to one or two staff members.

Similarly, the number of occupants on the bridge is not expected to be high. The bridge is a transient circulation space connecting Sussex Street to the commercial tower lobby.

15.5.3 Travel distances

The length of the bridge is approximately 15m. In the event of a fire beneath the bridge, occupants on the bridge are expected to be able to readily evacuate off the bridge and travel a short distance of up to 7.5m to a safe location on either side.

15.5.4 Sprinkler protection

The building and bridge is provided with sprinkler protection throughout. The presence of sprinkler system can be expected to control fire development, if not extinguish the fire – refer to section 15.6.2 for further information.

15.6 Assessment

15.6.1 Performance of structure

The acceptance criterion for this assessment is based on demonstrating that the proposed loadbearing structural elements such as steel provide adequate resistance when exposed to fire conditions.

The design of steel reinforced structural elements under fire conditions is based on critical steel temperature concept. This is a comparison of the yield strength and loading at normal conditions and the yield strength and loading conditions in fire conditions.

The change in yield strength at elevated temperature has been experimentally investigated. An approximation of this test data has been included in many national standards such as AS 4100-1998 (structural steel) as shown in Figure 50.

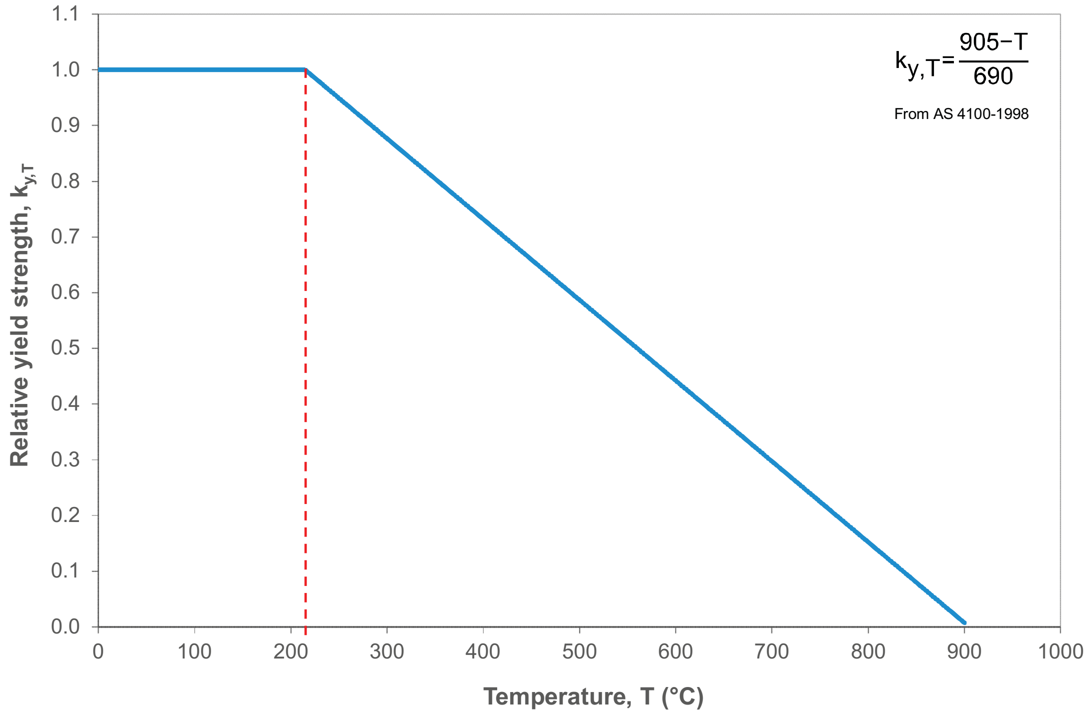


Figure 50 Design curves for reduction in yield strength of steel with temperature

The relationships show that the yield strength of structural steel when exposed to fire conditions does not reduce until the steel temperature reaches 215°C.

15.6.2 Impact of sprinklers

The covered area beneath the Wharf Lane bridge is proposed to be provided with a sprinkler system in accordance with specification E1.5 of the BCA and AS 2118.1-1999. The reliability of a sprinkler system, together with the impact that a sprinkler system will have on fire spread and fire intensity have previously been discussed in section 6.5.3.

As previously stated, the successful activation of the sprinklers can be expected to provide the following benefits:

- Reduction in the rate of burning and quantity of smoke produced, subsequently increasing in the available safe evacuation time.
- Reduced fire intensity and duration, which in turn reduces the severity of fire exposure to structural and fire separating elements.
- Reduction in the chances of a fire becoming large – ie spreading beyond the area / room of origin or flashover occurring.

It can generally be assumed that successful operation of the sprinkler system will have the following impact on compartment temperatures during a fire.

- The average temperatures outside the immediate area of operation of the sprinkler system are below 100°C.
- The temperature in the localised area above the fire is stated to be somewhat higher than the mean compartment temperature but is still unlikely to exceed 200°C.

The successful activation of the sprinkler system will limit the average compartment temperatures to below the critical temperatures for the steel structural elements of the bridge. Consequently, the assessment demonstrates that the structure is capable of resisting the effects of a sprinkler controlled fire.

15.6.3 Occupant evacuation beneath the bridge

The undercroft beneath the bridge is a back of house staff area of the Dundee Arms building that is not accessible to the general public. When occupied, the number of occupants at any one time is expected to be limited to one or two staff members. In the event of a fire beneath the bridge, occupants are considered to be able to quickly evacuate the immediate area without queuing at the exit.

Potential occupants of the Wharf Lane undercroft are staff who are expected to be reasonably familiar with the layout of the area and would be able to locate the exits promptly in the event of a fire given the small floor area of approximately 30m^2. Staff within this area are only there within the function of their employment and can therefore be assumed to be awake and aware of their surroundings should a fire occur. In addition, staff are expected to be able-bodied and are assumed to have the same level of mobility as the general population excluding those with disabilities.

15.6.4 Occupant evacuation from the bridge and hotel building

Occupants on the bridge or attempting to use the bridge are expected to have visual and olfactory cues to a fire beneath the bridge. Smoke is expected to rise via the voids located on either side of the bridge. Therefore, in the event of a fire occurring beneath, occupants above would evacuate the bridge and travel a short distance of up to 7.5m to a safe location on either side of the bridge.

For occupants evacuating from the commercial lobby or hotel building – via fire isolated stair 1 and 52 – an alternative path of travel to Sussex Street is available via the porte cochere as shown in Figure 49. Therefore in the event of a fire underneath the bridge or in the worst case scenario that the bridge structure fails, occupants can avoid using the bridge as a path of egress and exit to Sussex Street via the alternative egress route.

15.7 Conclusion

The assessment demonstrates that the non fire-rated bridge structure does not adversely impact occupants evacuating from the building. The proposed design of the Wharf Lane bridge is therefore considered to achieve compliance with performance requirements CP1 and DP4 of the BCA, subject to compliance with the fire safety measures given in section 5.

Appendix A Drawings and information

Drawing title	Dwg no	Date	Drawn
General arrangement plan – lower ground level	ZC-A-21-0B Rev13	21/03/2014	Cox Architecture
General arrangement plan – ground level	ZC-A-21-0G Rev14	21/03/2014	Cox Architecture
General arrangement plan – mezzanine level	ZC-A-21-0M Rev13	21/03/2014	Cox Architecture
General arrangement plan – level 1	ZC-A-21-01 Rev14	21/03/2014	Cox Architecture
General arrangement plan – level 2	ZC-A-21-02 Rev13	21/03/2014	Cox Architecture
General arrangement plan – level 3	ZC-A-21-03 Rev13	21/03/2014	Cox Architecture
General arrangement plan – level 4 to 10	ZC-A-21-04 Rev12	21/03/2014	Cox Architecture
General arrangement plan – level 11 to 15	ZC-A-21-11 Rev12	21/03/2014	Cox Architecture
General arrangement plan – level 16	ZC-A-21-16 Rev12	21/03/2014	Cox Architecture
General arrangement plan – level 17 to 23	ZC-A-21-17 Rev12	21/03/2014	Cox Architecture
General arrangement plan – level 24	ZC-A-21-24 Rev12	21/03/2014	Cox Architecture
General arrangement plan – sections 1 & 2	ZC-A-40-01 Rev7	28/02/2014	Cox Architecture
General arrangement plan – sections 3 & 4	ZC-A-40-02 Rev7	28/02/2014	Cox Architecture
General arrangement plan – sections 5 & 6	ZC-A-40-03 Rev7	28/02/2014	Cox Architecture
General arrangement plan – section 7	ZC-A-40-04 Rev6	28/02/2014	Cox Architecture
General arrangement plan – section 8	ZC-A-40-05 Rev6	28/02/2014	Cox Architecture
Ground north – fitout plan	ZC-AI-24-0G-N Rev4	07/03/2014	Bates Smart
Ground south – fitout plan	ZC-AI-24-0G-S Rev5	19/03/2014	Bates Smart
Mezzanine prefunction north – fitout plans	ZC-AI-24-0M-N Rev4	19/03/2014	Bates Smart
Mezzanine prefunction south – fitout plans	ZC-AI-24-0M-S Rev4	19/03/2014	Bates Smart
Ground north – RCP	ZC-AI-26-0G-N Rev4	07/03/2014	Bates Smart
Ground south – RCP	ZC-AI-26-0G-S Rev4	07/03/2014	Bates Smart
Mezzanine prefunction north – RCP	ZC-AI-26-0M-N1 Rev4	19/03/2014	Bates Smart
Mezzanine prefunction south - RCP	ZC-AI-26-0M-S1 Rev4	19/03/2014	Bates Smart
Ground north – FFE plan	ZC-AI-28-0G-N Rev2	07/03/2014	Bates Smart
Ground south – FFE plan	ZC-AI-28-0G-S Rev4	07/03/2014	Bates Smart
Mezzanine north – FFE plan	ZC-AI-28-0M-N Rev2	19/03/2014	Bates Smart
Mezzanine south – FFE plan	ZC-AI-28-0M-S Rev2	19/03/2014	Bates Smart

Other information	Ref no	Date	Prepared by
Draft BCA Report – Four Points by Sheraton Redevelopment	13-201181_FourPointsRedev_ DraftBCAReport_R01a_20052013	20/05/2013	Philip Chun Building Surveying
GF pax markup	-	29/11/2013	Bates Smart

Appendix B FRNSW comments on FEB and Defire response

The following table includes comments taken from the FEB meeting questionnaire FRN12/2196 (4429) V02 dated 20 March 2014 and responses from Defire.

FEBQ page ref	FRNSW comment	Defire response
7	The above populations have not been referenced. Please provide how the populations have been calculated and presented in Version 3 FEBQ and included in the FER.	Population densities used in this assessment are based upon population estimates provided by Bates Smart[57] and GL Investment Co[58].
10	It was noted during the FEB meeting that Ordinary 70 hydrant system in the existing building is proposed to up-graded and commissioned to comply with AS 2419.1-2005.	The existing building is currently undergoing an upgrade and the redeveloped and new building is proposed to comply with AS 2419.1-2005.
14	**Alternative solution 1 - design fires** It was discussed during the meeting that, the above fire scenarios will be reviewed to reflect the possible increased fuel load due to events held in the lobby area, e.g. such as fashion shows, etc. Given the events that may be held in the lobby area, possibility of a charismas tree presented and Class 6 tenancies opening into the atrium, it is recommended that a fire to 5MW be considered for fire scenario 1 above or further justification be provided.	Defire advised during the meeting that a 5MW fire had been considered due to potential fashion shows in on the lower ground floor below the heritage void. GL Investment Co advised during the meeting that the fashion shows would no longer be held following the redevelopment due to the reconfiguration of the lower ground resulting in reduced floor area that would make the fashion shows unfeasible. GL Investment Co also confirmed that Christmas trees are not currently, or proposed, to be located within the heritage void. Given this, it was discussed during the meeting that the fire scenario would be reviewed to reflect a decrease in the fire load that was originally assumed. The floor is a circulation lobby space used to process visitors entering the hotel. No significant fire load is expected within this area that would justify a 5MW fire.
14	**Alternative solution 1 – methodology for areas not provided with smoke exhaust** An AS1670.1 automatic fire detection and alarm system is a required system under Section 4 of Specification G3.8 of the BCA, if the extended travel distances occurring within atrium fire compartment.	Part G3 of the BCA does not apply to atriums that connect 3 storeys if each storey is provided with a sprinkler system and one of those storeys is situated at a level at which there is direct egress to a road or open space. The proposed building does not contain an atrium required to comply with part G3. Therefore an AS 1670.1 automatic fire detection and alarm system would not be required for the base case.

[57] Bates Smart markup, 161 Sussex Street – GF pax. 29 November 2013.
[58] GL Investment Co. Aconex GLIM-CA-000075 dated 13 December 2013.

FEBQ page ref	FRNSW comment	Defire response
15	**Alternative solution 1 – proposed trial design** Is the modelling program used for the design fire scenarios capable of factoring in the delay required for the semi-recessed arrangement of the head. This needs to be identified in the FER.	Semi-recessed sprinklers are not considered to significantly delay sprinkler activation as the sprinkler bulb is still located within the free air stream. This contrasts to fully recessed sprinklers or concealed sprinklers where the sprinkler bulb is not located within the free air stream and could delay activation. It is also noted that the design fires assessed conservatively assume a steady heat release rate after sprinkler activation rather than the fire being suppressed by the sprinkler system.
17	**Alternative solution 1 – redundancy** It is recommended that the reliability of the proposed smoke curtain and how critical the smoke curtains have impact on occupant safety in a fire event, is taken into consideration. Accordingly, failure or partial failure of smoke curtains be considered as a redundancy analysis.	A scenario has been modelled to assess the impact of a single smoke curtain failure scenario in the event of a fire in the lower ground floor as this could potentially lead to smoke spreading into the ground floor smoke zone. Refer to the assessment documented in section 5.7. Multiple smoke curtain failure is not considered to be a credible scenario.
23	**Alternative solution 4 (documented as alternative solution 5 in this report)** Clear justification of ventilation to equivalent fire severity calculation area is to be included. A variety of potential ventilation areas are to be evaluated and justified. In this regard, consideration should be given to height of openings, the size of the openings and their relationship to the height of the external wall [e.g. in a full height window only the upper portion may fail (See CIB Publication 269 – Rational Fire Safety Engineering approach to Fire Resistance of buildings)]. For this reason FRNSW recommend that a scenario with no more than 50% window breakage/failure be undertaken. Where it can be demonstrated that more than 50% breakage is likely to occur appropriate justification is to be included in the FER (e.g. modelling to demonstrate temperatures are sufficient to cause window breakage)	Refer to Appendix D. No scenario with more than 50% window breakage has been considered.
31	**Alternative solution 7 (documented as alternative solution 8 in this report)** There is inconsistency in the FRL of the proposed fire curtains and needs to be clarified.	The fire curtains separating the discharge location of fire stair 2 from the remainder of the building are required to achieve an FRL of not less than -/60/-.
31	**Alternative solution 7 (documented as alternative solution 8 in this report)** A scenario where the fire curtains fail to deploy to the close position is to be discussed.	This is discussed in section 13.6.1.
34	**Alternative solution 8 (documented as alternative solution 9 in this report)** It appears the proposed alternative solution complies with Clause 3.5 of Spec C1.1. Otherwise, the DTS complying design is to be detailed.	The certifying authority has deemed that the roof trusses do not qualify for the concession under clause C3.5 of specification C1.1 of the BCA.

FEBQ page ref	FRNSW comment	Defire response
38	**Alternative solution 9 (documented as alternative solution 10 in this report)** It is not clear what the use of the area beneath the bridge is.	The undercroft is a back of house staff area connected to the Dundee Arms building, however it is not intended to be used as a storage space due to its visual presence below the Wharf Lane bridge which acts as a primary entry to the commercial tower. The building and bridge is provided with sprinkler protection throughout

Appendix C Existing annual fire safety statement

Annual Fire Safety Statement

Issued under Part 9 of the Environmental Planning and Assessment Regulation 2000

Type of statement	Critical ☐ Annual ☑	
Annual Statement **Name** **Address**	I Matthew Worth. Of Four Points by Sheraton 161 Sussex St Sydney certify that: 1) Each essential fire safety measure listed below has been assessed by a properly qualified person; and 2) Each essential fire safety measure was found, when it was assessed: a) Where an essential fire safety measure applies because it is specified in the fire safety schedule for the building, to be capable of performing to at least the standard set out in the schedule; or b) Where an essential fire safety measure applies although it is not specified in a fire safety schedule for the building, to be capable of performing to at least the standard for which the measure was originally designed and implemented; and 3) The building has been inspected by a properly qualified person and was found, when it was inspected, to be in a condition that did not disclose any grounds for a prosecution under Division 7. 4) The information contained in this statement is true and accurate to the best of my knowledge and belief.	
Identification of building	Street Suburb Number / name Building assessed Part/whole	Sussex Street, Sydney 161 Whole
Date of assessment	Dated this	15 June 2012
Owners details	Name Address	EP 2 Management
Essential Fire Safety Measures	**Existing Measure**	**Standard of Performance**
	Access panels, doors & hoppers to fire-resisting shafts	Part 22.12 & AS 1905.1 - 2009
	Automatic fire detection & alarm systems	AS 1670-1986
	Automatic fire suppression systems	AS 2118 - 1982
	Automatic fire suppression systems Kitchen suppression system	AS3772-1990
	Emergency lifts	Ord 70 Part 55.9, Ord 70 Part 22.8 & AS 1735.11 - 1986
	Emergency lighting	Clause E4.2 BCA 90, AS2293.1 - 1987
	Emergency warning & intercommunication systems	Clause E4.9 BCA90, AS2220.1 .2-1989
	Exit signs	Clauses E4.5, 4.6, 4.8 BCA90, AS2293.1 - 1987
	Fire alarm monitoring	AS 4428.6 - 1997, AS 3013 - 1995, AS 1670.3 - 1997
	Fire control centres & rooms	Part 27.7 Ordinance 70, Ministerial Spec 11
	Fire dampers	Ord 70 Part 22.13 & AS 1682.1 - 1990
	Fire doors	clause C3 of BCA 90 and AS1905.1-1990
	Fire hydrant systems	Part 27.3 Min Spec 10 Ordinance 70
	Fire seals protecting openings in fire-resisting components of the building	Part 22.13, 55.5 Ordinance 70
	Hose reel systems	Part 27.2 Min Spec 10 Ordinance 70
	Mechanical air handling systems	Ord 70 Part 55.7 & AS 1668.1 - 1991
	Paths of Travel	Division 7 EP&A Regulations 2000
	Portable fire extinguishers	Clause E1.6 BCA 1990, AS2444 - 1981
	Pressurising systems	Part 55.15(2), 55.8 Ordinance 70
	Solid core doors	Part 22.9 (3) (b) Ordinance 70
	Standby power systems	Ord 70 Part 55.15(2)
	Wall-wetting sprinkler and drencher systems	Part 22.4. 2b AS 2118-1982
	Warning and operational signs	Clause 183 EPA Regulations 2000
Date of statement	11 - 7 - 2012	
Signature	Owner / owners behalf	

Appendix D Equivalent fire severity calculations

D.1 Standard furnace test

The FRL of an assembly or structural element is determined empirically through the use of a standard furnace test in accordance with AS 1530.4-2005[59]. This test exposes elements to the standard heating regime as shown in Equation 2 and Figure 51.

$$T_t - T_0 = 345 \log_{10}(8t+1)$$

where:

T_t = Furnace temperature at time, t (°C)

T_0 = Initial furnace temperature at time (°C)

t = Time from ignition of furnace (minutes)

Equation 2 Standard heating regime

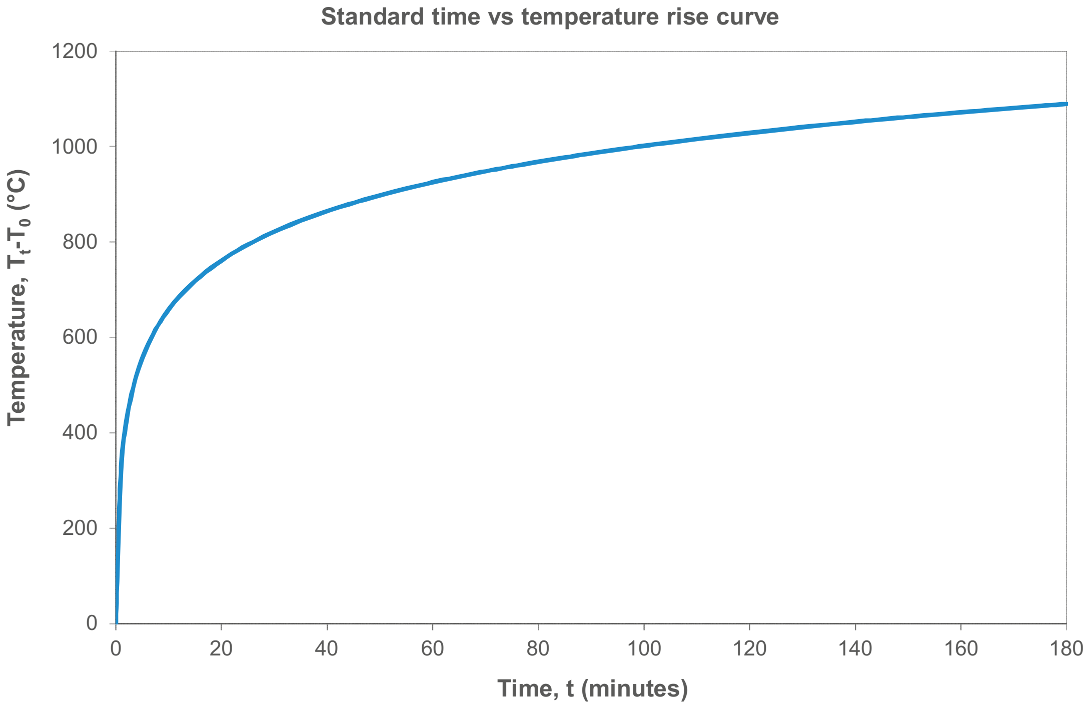


Figure 51 Standard heating regime

The performance of building elements is measured across three main categories:

- Structural adequacy – the ability of a loadbearing element of construction to support a load.
- Integrity – the ability of an element of construction to resist the passage of flames and hot gases from one space to another.
- Insulation – the ability of an element of construction to maintain a temperature on the surface that is not exposed to the furnace, below the limits specified.

The criterion for failure in each of these categories is specified under clause 2.12 of AS 1530.4-2005.

[59] AS 1530.4-2005, Methods for fire tests on building materials, components and structures – Part 4: Fire-resistance tests of elements of building construction, Standards Australia, Australia.

An element or assembly may not be required to achieve a rating in all categories – eg a non-loadbearing assembly will not be tested for structural adequacy.

D.2 Equivalent fire severity

The standard fire test provides a means of empirically determining the resistance of an assembly to a severe fire and comparing the performance of different assemblies. The standard heating regime does not represent the expected compartment temperatures expected for real fires. This is a function of the fuel load and compartment geometry. A fully developed fire in a compartment is likely to have higher peak temperatures than the standard fire, but remain at these peak temperatures for a shorter duration.

To address the differences in expected compartment temperatures between real fires and the standard fire test a number of correlations have been developed. These correlations aim to determine the severity of a real fire in comparison to the standard fire test. The most common method of determining this is to examine the expected maximum temperature of elements exposed to a real fire in comparison to elements exposed to a standard fire. This method defines the equivalent fire severity as the time of exposure to the standard fire test that would result in the same maximum temperature in an element exposed to the complete burnout of the fire compartment. This process is illustrated in Figure 52.

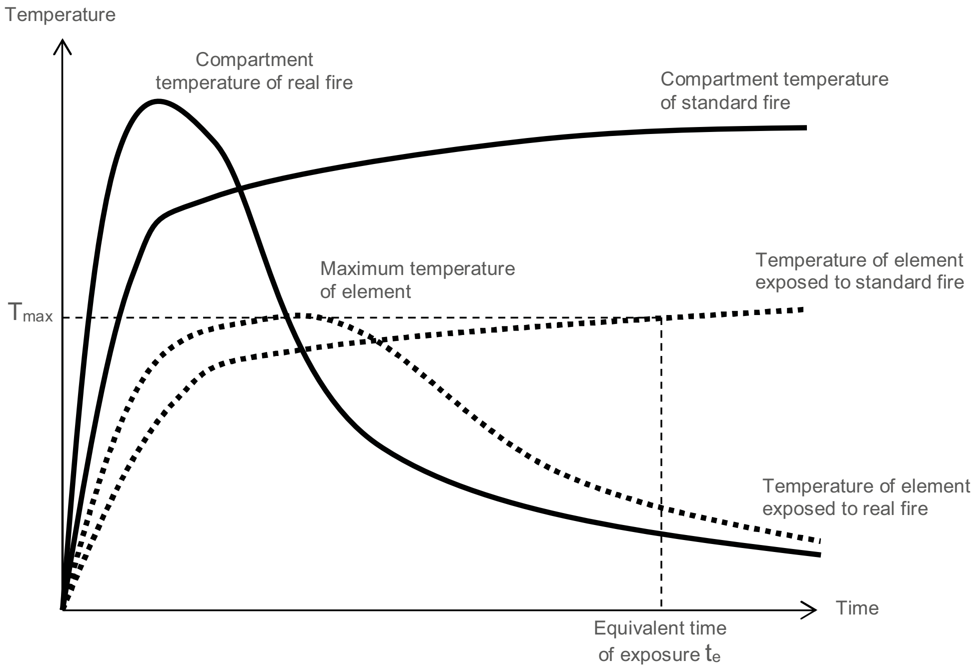


Figure 52 Equivalent fire severity

D.2.1 Eurocode

One method of determining the equivalent fire severity is included within Eurocode 1. This method is outlined within Equation 3.

$$t_e = q_{f,d} k_b W_f$$

where:

- t_e = equivalent fire severity (minutes)
- $q_{f,d}$ = fire load per unit floor area (MJ/m2)
- k_b = conversion factor
- W_f = ventilation factor

$$W_f = \left(\frac{6}{h}\right)^{0.3} \frac{0.62 + 90(0.4 - \alpha_v)^4}{(1 + b_v \alpha_h)}$$

where:

- α_v = ratio of area of vertical openings in the façade to the floor area of compartment (Av/Af)
  $0.025 < \alpha v < 0.25$
- α_h = ratio of area of horizontal openings in the roof to the floor area of compartment (Ah/Af)
- h = height of fire compartment (m)
- b_v = $12.5(1+\alpha v10-\alpha v2) \geq 10$

Equation 3 Eurocode 1: Part 2.2 method for determining equivalent fire exposure

D.2.2 BS 9999

Another method of determining the equivalent fire exposure is specified within British Standard 9999[60]. This method is outlined in Equation 4.

$$t_e = \frac{k_b q_{f,d} A_f}{\left(A_t A_v \sqrt{h}\right)^{0.5}}$$

where:

- t_e = equivalent time of exposure (minutes)
- $q_{f,d}$ = fire load per unit floor area (MJ/m2)
- A_f = floor area (m2)
- A_t = total area of compartment including openings (m2)
- A_v = area of vertical openings (m2)
- k_b = conversion factor
- h = height of vertical openings (m)

Equation 4 BS 9999 method for determining equivalent fire exposure

[60] CIBSE Guide E: Fire Engineering, 2010, 3rd edition, CIBSE, London, UK.

D.2.3 Conversion factor

Both correlations are dependent on the conversion factor (k_b). This factor represents the construction of the compartment which influences the heat transfer to protected structural members. As the level of insulation provided within the compartment increases so do the conversion factor and equivalent fire severity.

The required value of k_b varies, CIBSE Guide E states that for the BS 9999 correlation the conversion factor should be taken as 0.07. Eurocode provides guidance on a range of conversion factors, but states when no detailed assessment of the thermal properties of the enclosure is made that the conversion factor may be taken as 0.07. Kirby [61] gives guidance on the conversion factor for large compartments based on experiments within a compartment measuring 23 x 5.5 x 2.7 metres. The various conversion factors are summarised in Table 25.

$b = (k\rho c_p)^{0.5}$	Example construction	Correlation		
		CIBSE Guide E for BS 9999 correlation	Eurocode	Large Compartments
High (> 2500)	Steel	Not specified	0.04	0.05
Medium (720-2500)	Normal and lightweight concrete	Not specified	0.055	0.07
Low (< 720)	Gypsum plaster	Not specified	0.07	0.09
General		0.07	0.07	0.09

Table 25 Values of conversion factor (k_b)

D.2.4 Variation between correlations

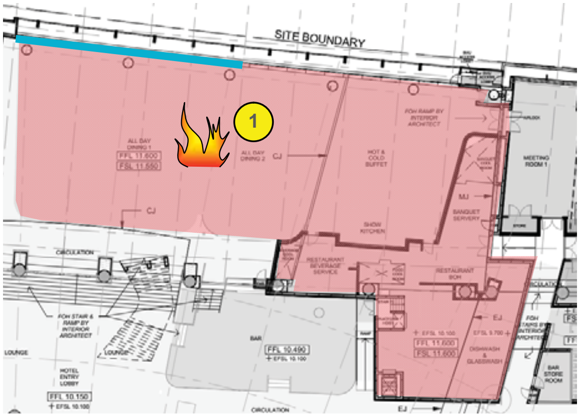
The two correlations presented vary in the way they relate the equivalent fire severity to the compartment geometry. The most notable difference is that the Eurocode method is dependent on the compartment floor to ceiling height and the BS 9999 method is dependent on the height of the openings.

These differences will result in variations in the resultant equivalent fire severity recorded for the same compartment geometry. To account for this variation and to add a level of conservatism to the assessment both correlations will be assessed and the maximum value of equivalent fire severity will be used in the assessment.

[61] Buchanan AH, 2001, Structural design for fire safety, 2nd edition, Wiley & Sons.

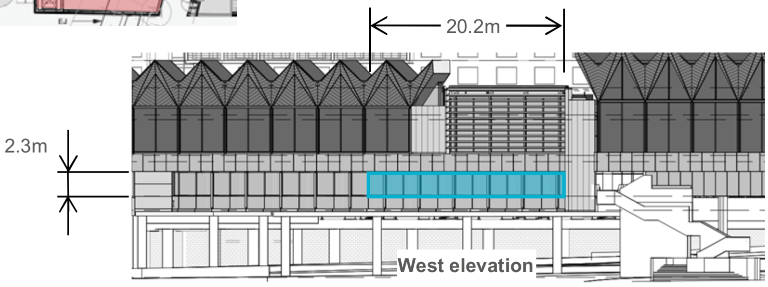
D.3 Results

D.3.1 Fire scenario 1 – Ground floor, restaurant and kitchen (926m^2)



Legend

- Area to be assessed
- Location of glazing breakage assumed
- Size of glazing breakage



The size of the opening is based upon 50% breakage of the restaurant window glazing – flashover fire assumed.

Equivalent time of exposure to standard furnace test from Eurocode 1 and CIBSE Guide E

Input

Room parameters

Depth =	48.0	m
Width =	19.3	m
Height =	3.0	m
Floor area =	926.4	m²

Building design and use parameters

Fuel load =	480	MJ/m²
Conversion factor (k_b) =	0.07	

Vertical opening details

Number	1	2	3	4	5	6	7	8	9	10	11	12
Width (m)	20.2											
Height (m)	2.3											

Horizontal opening details

Number	1	2	3	4	5	6	7	8	9	10	11	12
Width (m)	0	0	0	0	0	0	0	0	0	0	0	0
Length (m)	0	0	0	0	0	0	0	0	0	0	0	0

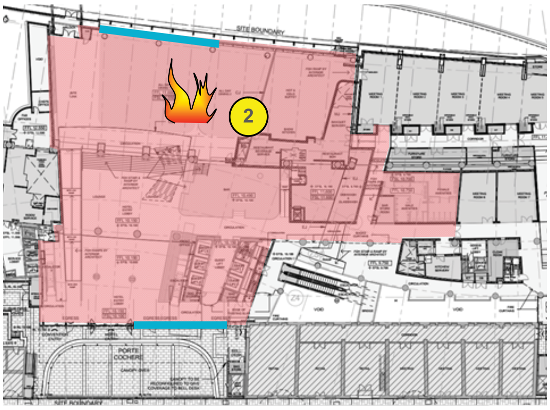
Results

A_t=	2,256.6	m²	Total surface area	a_v=	0.05	0.025 < av < 0.25
A_v=	46.5	m²	Area of ventilation	a_h=	0.00	
h=	2.3	m	Equivalent height of openings	b_v=	18.74	b_v > 10
				w_f=	2.42	

	Eurocode method	BS 9999 method
Equivalent time of exposure	81 minutes	78 minutes

Maximum equivalent time of exposure	81 minutes

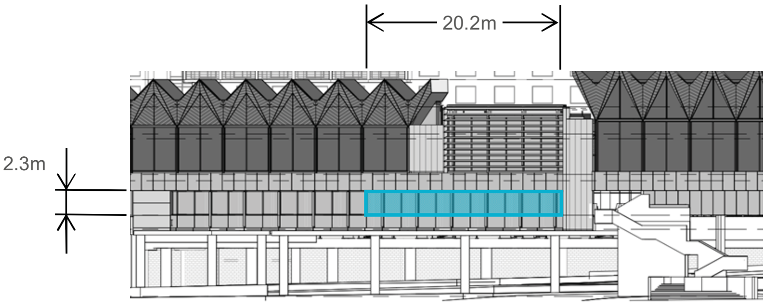
D.3.2 Fire scenario 2 – Ground floor, restaurant and main lobby (2550m²)



Legend

- Area to be assessed
- Location of glazing breakage assumed
- Size of glazing breakage

East elevation



West elevation

The size of the opening is based upon 50% breakage of the restaurant window glazing and 50% breakage of the low level hotel entry glazing – flashover fire assumed.

Equivalent time of exposure to standard furnace test from Eurocode 1 and CIBSE Guide E

Input

Room parameters			Building design and use parameters		
Depth =	51.0	m	Fuel load =	480	MJ/m²
Width =	50.0	m	Conversion factor (k_b) =	0.07	
Height =	3.9	m			
Floor area =	2550.0	m²			

Vertical opening details

Number	1	2	3	4	5	6	7	8	9	10	11	12
Width (m)	20.2	15										
Height (m)	2.3	3										

Horizontal opening details

Number	1	2	3	4	5	6	7	8	9	10	11	12
Width (m)	0	0	0	0	0	0	0	0	0	0	0	0
Length (m)	0	0	0	0	0	0	0	0	0	0	0	0

Results

A_t=	5,887.8	m²	Total surface area	a_v=	0.04	0.025 < av < 0.25
A_v=	91.5	m²	Area of ventilation	a_h=	0.00	
h=	2.6	m	Equivalent height of openings	b_v=	16.97	b_v > 10
				w_f=	2.51	

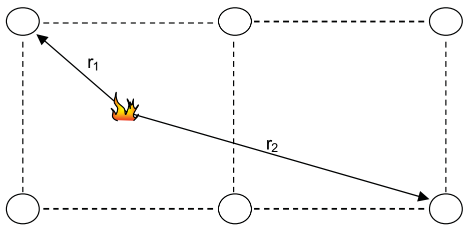
	Eurocode method	BS 9999 method
Equivalent time of exposure	84 minutes	92 minutes
Maximum equivalent time of exposure		92 minutes

Appendix E Sprinkler activation calculations

Sprinkler activation

Nomenclature

H	height of ceiling above the fire (m)
u	gas velocity (m/s)
T_a	ambient temperature (deg C)
T_g	ceiling jet temperature (deg C)
Q	fire heat release rate (kW)
r	radial distance from the plume to the sprinkler location (m)
T_d	detector temperature (deg C)
RTI	response time index ($m^{0.5}s^{0.5}$)
C	C factor ($m^{0.5}s^{-0.5}$)



$r = r_1$ or r_2 depending on first or second row activation

Formulae (based on Alpert's correlations)

$T_g - T_a = 16.85\ Q^{2/3}\ H^{-5/3}$ $r/H <= 0.18$

$T_g - T_a = 5.36\ (Q/r)^{2/3} / H$ $r/H > 0.18$

$u = 0.945\ (Q/H)^{1/3}$ $r/H <= 0.15$

$u = 0.197\ Q^{1/3}\ H^{1/2}\ r^{-5/6}$ $r/H > 0.15$

Source: Alpert R L (1972), Calculation of response time of ceiling mounted fire detectors, *Fire Technology*, 8(3), pages 181 - 195

$dTd = (u^{0.5} / RTI)\ [(T_g - T_{room}) - (1 + C\ u^{-0.5})(T_d - T_{room})]\ dt$

Source: Heskestad G and Bill R G (1988), Conduction heat-loss effect on thermal response of automatic sprinklers, *Fire Safety Journal*, v.14, pages 113-125

Ambient temperature 21 °C

Fire location	Fire growth	H	r	Act. °C	RTI	C	Act. time (s)	Fire size (MW)
Ground floor bar fire	Medium	3.4	2.5	68	50	0.8	**298**	**0.99**
Sensitivity - ground floor bar fire 2nd row activation	Medium	3.4	5.5	68	50	0.8	**461**	**2.36**
Mezzanine southern pre-function	Medium	3.9	2.5	68	50	0.8	**322**	**1.15**

Appendix F FDS smoke modelling assessment

F.1 Introduction

This section provides a brief overview of Fire Dynamics Simulator (FDS) Version 5[62,63] for the purposes of familiarisation. The theoretical basis of FDS is described in detail within the FDS Technical Reference Guide. The FDS User's Guide provides a thorough explanation of how to setup and perform simulations.

The FDS model was developed specifically for modelling building fires. FDS is a computational fluid dynamics (CFD) model generally applied to fire-driven fluid flow. In FDS, the computational domain is discretised into three dimensional rectilinear volumes referred to as the grid or mesh. The partial derivatives of the conservation equations of mass, momentum and energy are approximated as finite differences, and the solution is updated in time on the rectilinear grid.

The geometry specified by the user in FDS conforms to the rectilinear grid and hence is limited by the resolution of the grid. Similarly, boundary conditions such as vents are applied as patches on the exterior of the domain which will also conform to the rectilinear grid.

Output from the simulation is included in this appendix at various times so the ability of occupants to safely evacuate from the fire and smoke affected areas can be assessed.

F.2 FDS input parameters

F.2.1 General

The following general parameters were applied in the FDS models described in this section:

- Turbulence was modelled using Large Eddy Simulation (LES). In a LES, the larger geometry dependant eddies are solved explicitly and the smaller eddies are filtered using a sub-grid scale model.
- The combustion model which FDS utilises for LES application is based on a mixture fraction. The mixture fraction is 'a conserved scalar quantity that is defined as the fraction of gas at a given point in the flow field that originates as fuel' – ie at the surface of a burning fuel the mixture fraction is 1 and in fresh air the mixture fraction is 0.
- All walls, columns, ceilings and floors are assumed to be INERT, ie non-reacting solid boundary fixed at ambient temperature. This is considered an acceptable approximation as the heat transfer from the smoke to surrounding structures for areas remote from the fire is relatively low for localised fires.
- Mechanical exhaust and supply were modelled as a volume flux (m^3/s) from and into the domain respectively.
- Makeup air openings were modelled as passive openings to an infinite reservoir, ie no significant over- or under-pressure can be created, with outside temperature the same as the initial internal temperature.
- Air is the only fluid simulated with the computational domain at the commencement of the simulation.
- The temperature for the ambient environment has been specified as 20°C.

[62] National Institute of Standards and Technology (NIST), FDS and Smokeview (SMV), USA, United States Department of Commerce, http://code.google.com/p/fds-smv/, accessed 6 August 2013.
[63] K McGrattan et al, NIST Special Publication 1019-5: Fire Dynamics Simulator (Version 5) – User's Guide, USA, United States Department of Commerce, 2010.

F.2.2 Fire properties

The design fuel for the scenarios modelled was based on a mixture of combustibles listed in Table 26.

Material	Mass percentage	Volume percentage
Wood	40%	29%
Nylon	15%	11%
PVC	15%	17%
Polyurethane	15%	18%
Polystyrene	15%	26%

Table 26 Mixture of combustibles

The mixture of combustible was chosen to represent generic building materials and contents such as cellulosic materials, textile fabrics, rigid plastics, expanded plastics and upholstery foam found in typical building occupancies. The properties of the combined fuel in comparison to the individual components are shown in Table 27.

	Wood	Nylon	PVC	Polyurethane	Polystyrene	Average mixture
Common use	Shelving and building partitions	Clothing	Rigid plastics	Upholstery/ furniture	Packing materials	-
Heat of combustion (kJ/g)	17.7	30.8	16.4	27.2	39.2	22.5
Soot yield (g/g)	0.015	0.075	0.14	0.23	0.16	0.1
CO yield (g/g)	0.006	0.028	0.053	0.086	0.060	0.037
Mass optical density (m²/g)	0.037	0.23	0.40	0.33	0.34	0.21
Heat of combustion, CO yield and mass optical density data for components taken from Enclosure Fire Dynamics[64]. Property for mixture and CO yield for all materials derived using method outlined in FDS Users guide[65].						

Table 27 Combustion product yields for design fire

The resulting material reaction that was used within FDS is as follows:

&REAC ID	=	'MIXED_COMBUSTIBLES'
FYI	=	' 40% Wood, 15% PVC, 15% Polyurethane, 15% Nylon, 15% Polystyrene'
C	=	1
H	=	1.764
O	=	0.385
CO_YIELD	=	0.037
VISIBILITY_FACTOR	=	2.303
SOOT_YIELD	=	0.1
MASS_EXTINCTION_COEFFICIENT	=	8700
IDEAL	=	.FALSE. /

[64] B Karlsson, JG Quintiere, Enclosure Fire Dynamics, CRC Press, 2000.
[65] K McGrattan et al, NIST Special Publication 1019-5: Fire Dynamics Simulator Version 5 – User's Guide, USA, United States Department of Commerce, 2010.

F.2.3 Visibility factor

The visibility calculation in FDS, which by default is based on a reflective exit sign, has conservatively been adjusted by reducing the 'VISIBILITY FACTOR' from 3.0 to 2.3 – ie by increasing the light attenuation in the smoke by a factor of 1.3. This adjustment is required to ensure that FDS calculates the visibility to non-illuminated walls and obstructions such that a predicted visibility of 10m correlates to a smoke optical density of $0.1m^{-1}$ or 1.0dB/m in accordance with the Fire Engineering Guidelines.

Where queuing locally in front of an exit occurs a higher visibility factor of 8 should be applied, representing the visibility to an illuminated exit sign. As only one visibility factor can be modelled this will be accounted for by assessing when a visibility of 2.9m is reached at the exits, being equivalent to a visibility of 10m to an illuminated exit sign.

F.1 Grid resolution

F.1.1 Available research on grid resolution

Validation tests of FDS have been undertaken by NIST. Three experiments were completed where a pool of heptane was burned and gas temperatures were collected. The room measured 27m long, 14m wide and 19m high with a sloped ceiling, an exhaust duct and several doors opening at the base of the room. The analysis region surrounding the fire measured 4m by 4m by 10m high with computational cells that measured 0.13m. Further away from the fire larger grids were used. The modelling resulted in calculations that agreed reasonably well with the measurements where the upper thermocouples were within 10°C of the measured temperatures that varied between 100°C and 150°C above ambient. The lower layer measurements were also within 10°C with these temperatures between 20°C and 100°C but the measurement near the floor under predicted the temperature by approximately 10°C[66].

Research undertaken by the University of Canterbury concluded that the grid size could have a significant impact on the results and was dependent on the geometry of the enclosure. It was concluded that the temperature predictions in the fire and plume were unreliable unless a fine grid was used but a finer grid outside the fire region did not necessarily mean more accurate predictions. Comparisons to US Navy hangar tests concluded that a 600mm grid over-predicted the temperatures by as much as 200°C in the region of the fire plume while away from the fire the predictions were more accurate near the ceiling[67]. Therefore in modelling smoke in the region away from the fire, the results are not as sensitive to grid size. For the smoke modelling conducted in this assessment the exact characteristics of the plume are not the main concern, rather the conditions in the smoke layer far from the plume are of interest.

A comparison of FDS model predictions with experiments conducted in a hangar with a 15m ceiling concluded that a reasonable agreement with empirical plume correlations were achieved when the spatial grid in the vicinity of the fire is about one tenth of the characteristic fire diameter[68].

F.1.2 Calculation of characteristic fire diameter

The research presented in F.1.1 concluded that the cell size within the fire region should be approximately one-tenth the characteristic fire diameter. Equation 5 shows the formula for the characteristic fire diameter.

$$D^* = \left(\frac{Q}{\rho_\infty T_\infty c_p \sqrt{g}} \right)^{2/5}$$

Where:

D^* = Characteristic fire diameter (m)

Q = Heat release rate (kW)

ρ_∞ = Density of ambient air (kg/m^3)

[66] McGrattan KB et al, Fire Dynamics Simulator (Version 5) Technical Reference Guide, Volume 3, NIST Special Publication 1018-5, October 2010.

[67] Petterson N, 'Assessing the Feasibility of Reducing the Grid Resolution in FDS Field Modelling', University of Canterbury, NZ 2002

[68] Davis W et al, 'Comparison of Fire Model Predictions with Experiments Conducted in Hangar with a 15 meter Ceiling', NISTIR 5927. US 1996

T_∞ = Ambient air temperature (K)

c_p = Heat capacity of ambient air (kJ/kg-K)

g = Gravity (m/s²)

Equation 5 Characteristic fire diameter

F.1.3 Modelled grid resolution

Based on the information provided in sections F.1.1 and F.1.2 the grid resolution summarised in Table 28 is considered acceptable for the purpose this assessment and provides an appropriate estimation of the overall smoke movement and temperatures.

Using Equation 5 and a varying fire sizes of 1MW to 2.36MW, the characteristic fire diameters range between 0.95m to 1.34m. This corresponds to a recommended grid size of 0.1 to 0.13. A uniform grid size of 0.25m was modelled for the fire region. Although this is higher than the 1/10th characteristic fire diameter, it is considered to provide a reasonable grid resolution as the purpose of the model is to estimate smoke spread remote from the fire and a safety factor is applied to the comparison of ASET/RSET. The aspect ratio of the cells in the models is maintained within the recommended limit of 1:3 in the FDS manual.

Area	Direction	Cell size (m)
Fire region	x-direction	0.25
	y-direction	0.25
	z-direction	0.25
Away from fire region	x-direction	0.5
	y-direction	0.5
	z-direction	0.25

Table 28 Grid resolution

F.2 Smoke detection

Smoke detector devices have been included in the FDS models for each of the fire scenarios to activate the mechanical smoke exhaust and makeup air. The time to smoke detector activation predicted by the FDS models has also been used as the cue time for the evacuation calculations for each scenario.

The Heskestad model was used to prescribe smoke detector properties in FDS. The Heskestad model requires the user to input values for the characteristic length 'LENGTH' and activation obscuration 'ACTIVATION_OBSCURATION'.

The characteristic length represents a transport delay for smoke to move from outside a detector to the sensor. Bukowski and Averill[69] state that the 'characteristic length (L) can be neglected in the room of origin if the detector is in the ceiling jet… elsewhere a default value of 2m could be used in the absence of actual data'. The FDS user manual suggests using 1.8 for unidentified ionization detectors.

The default value of 3.8 for 'ACTIVATION_OBSCURATION' is specified by FDS5. AS 1603.2-1997 – Automatic fire detection and alarm systems – Point type smoke detectors – requires the following range of performance for point type smoke detectors:

[69] RW Bukowski and JD Averill, Methods for Predicting Smoke Detector Activation. Fire Suppression and Detection Research Application Symposium, Research and Practice: Bridging the Gap, USA, NIST, 1998.

TABLE 2.1

SENSITIVITY LEVELS FOR SMOKE DETECTORS

Classification	Sensitivity			
	Value	Nominal (S)	Individual minimum	Individual maximum
Photoelectric	%Obs/m	0 to 15	$1.5S$ or $S+2$	$0.5S$ or $S-2$
Ionization	MIC X	0 to 0.4	$1.5S$ or $S+0.03$	$0.5S$ or $S-0.03$

Clause 4.10.2 of AS/NZS 1668.1:1998 states that smoke detectors for system control shall comply with the following:

a. Occupied space detectors –

   i. photoelectric – nominal response threshold of not more than 8% Obs/m (AS 1603.2); or

   ii. ionization – nominal response threshold of not more than 0.4 MIC X (AS 1603.2); or

   iii. multi-point-aspirated smoke detectors – nominal response threshold determined for each sampling point shall not be more than 4% Obs/m (AS 1603.8).

Based on the information provided above, a characteristic length of 2 and an activation obscuration of 8 has been used to define the detectors in the FDS models for this assessment.

Smoke detectors have been located in the FDS models in accordance with AS 1670.1-2004. Detectors have been located around the fire to maximise the distance between the fire and detectors as shown in Figure 53.

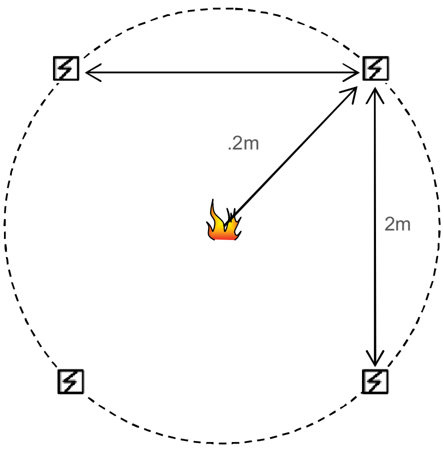


Figure 53 Location of smoke detectors in FDS models

F.3 Model geometry

F.3.1 Scenario 1

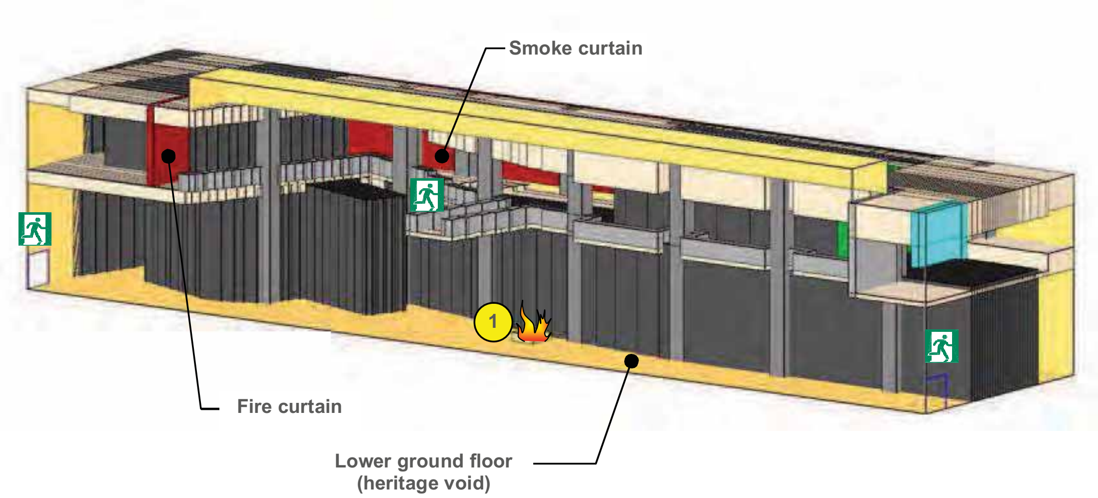


Figure 54 Model geometry for scenario 1

F.3.2 Scenarios 2, 3, 4 and 5

The model geometry for fire scenario 2 is shown in Figure 55, Figure 56 and Figure 57 . The geometry for fire scenarios 3, 4 and 5 is identical with the exception of the fire location.

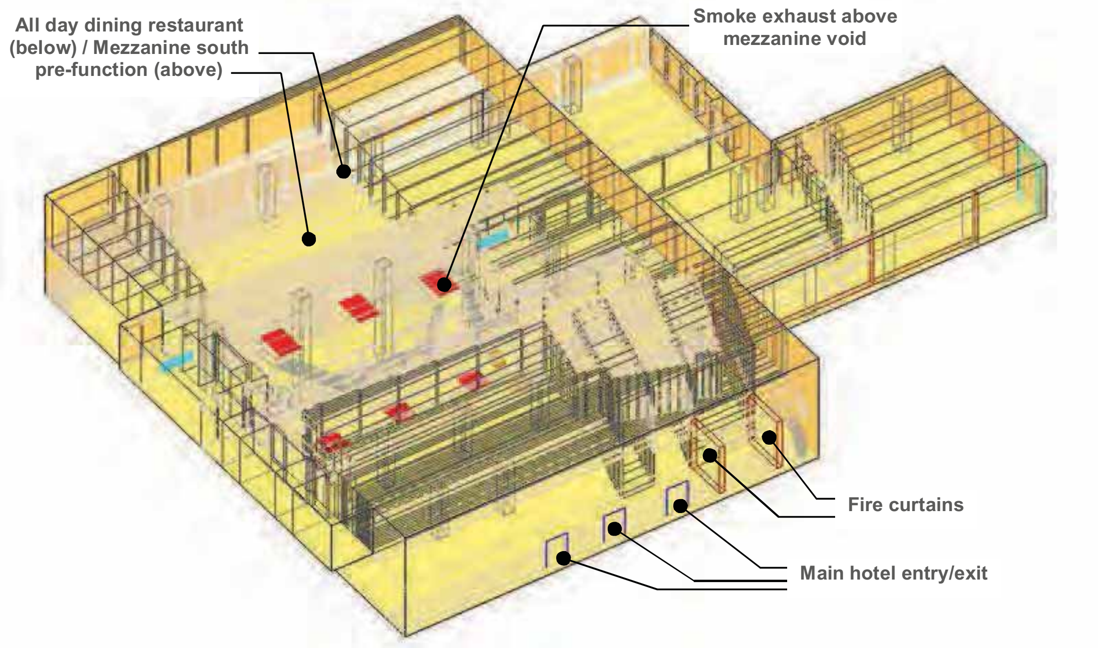


Figure 55 Model geometry for scenarios 2, 3, 4 and 5

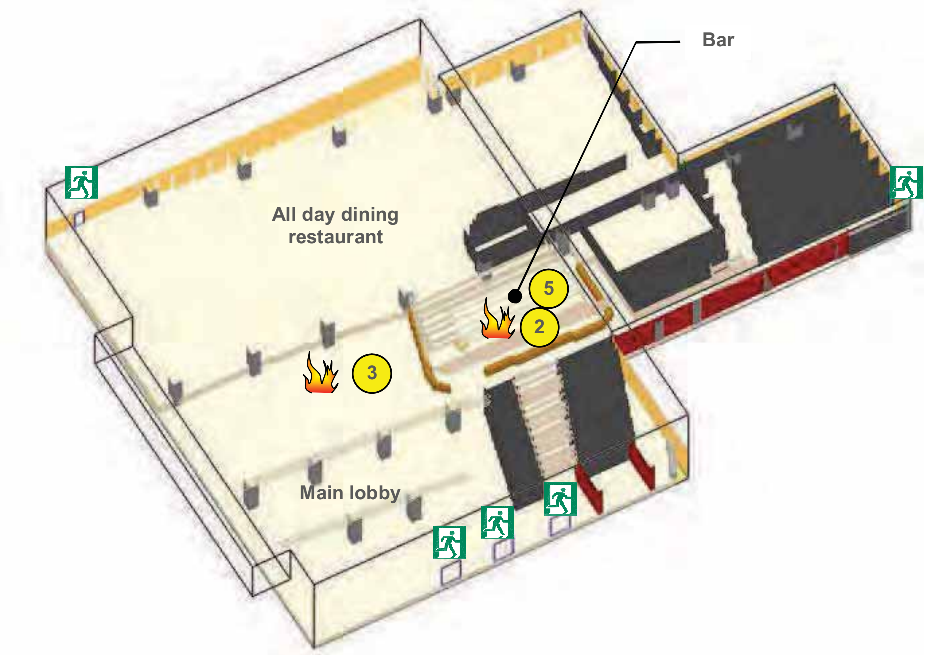


Figure 56 Model geometry for scenarios 2, 3, 4 and 5 – southern ground floor

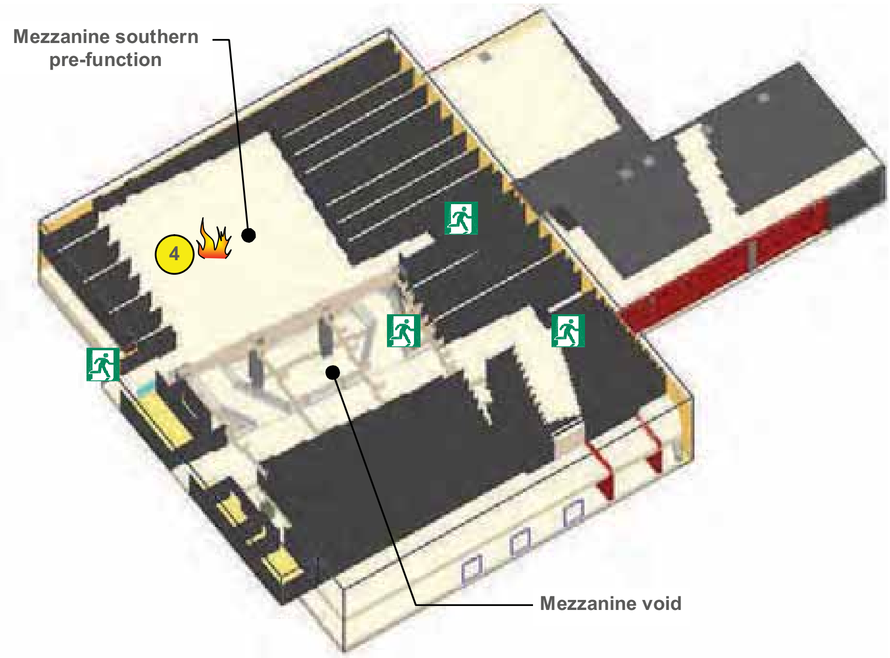


Figure 57 Model geometry for scenarios 2, 3, 4 and 5 – southern mezzanine floor

F.3.3 Scenario 6

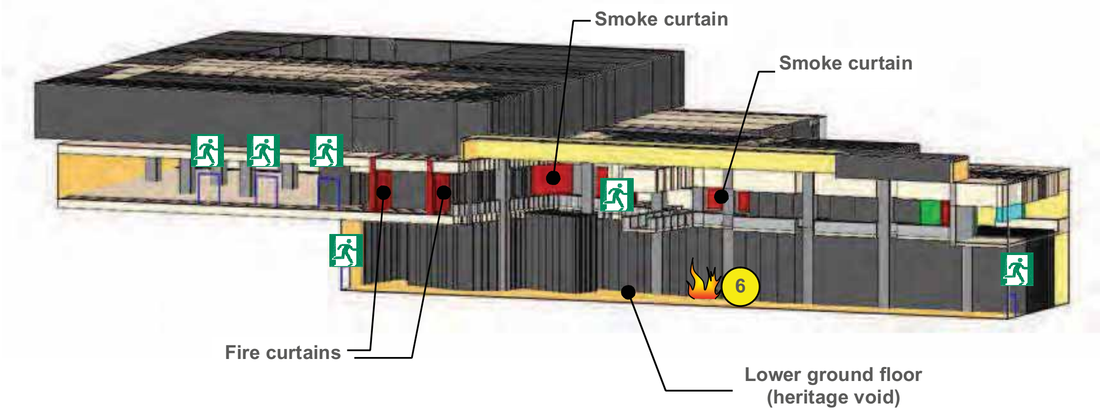


Figure 58 Model geometry for scenario 6

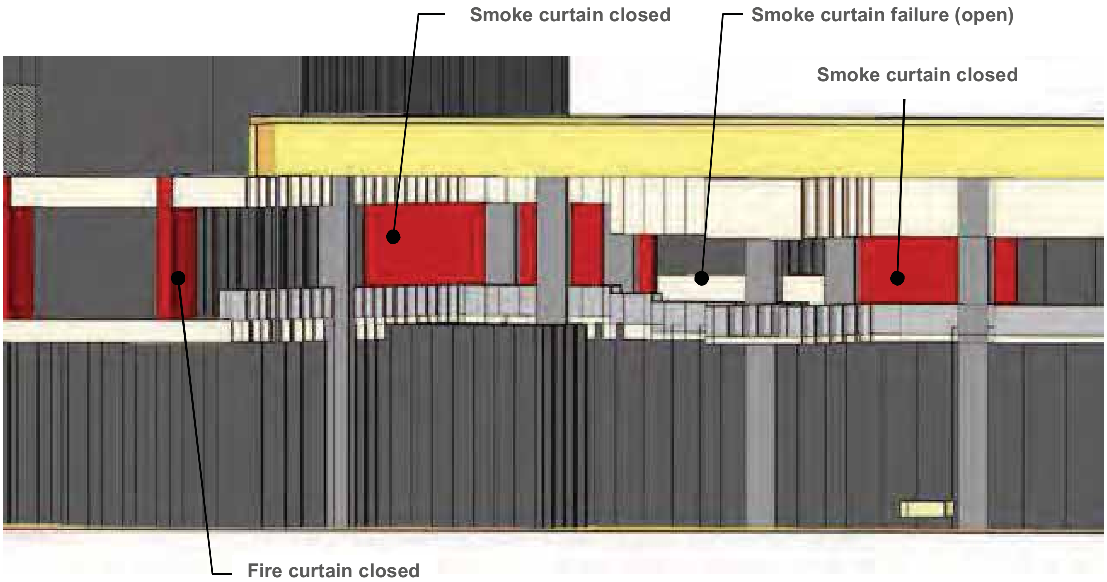
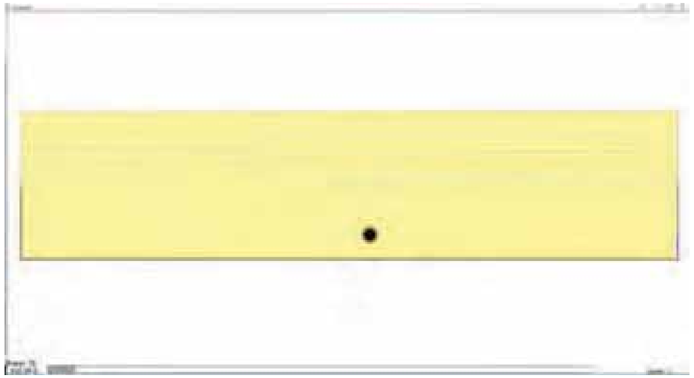
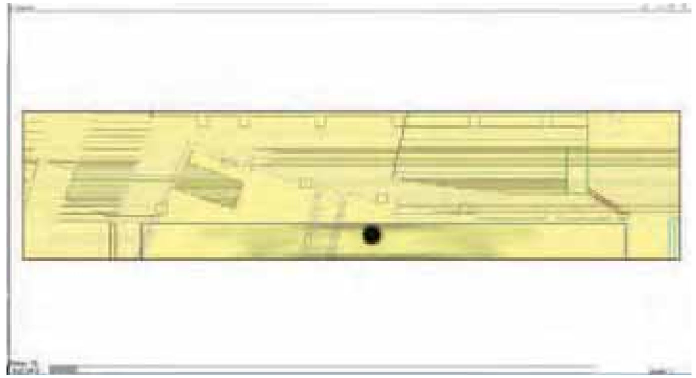
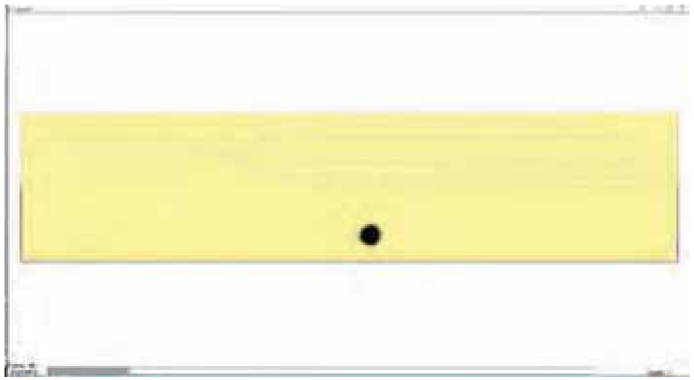
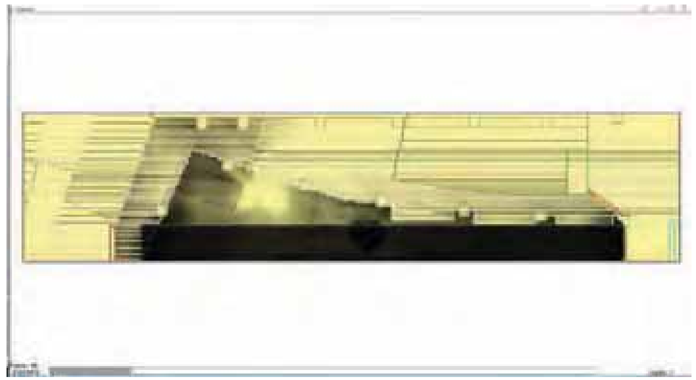


Figure 59 Model geometry for scenario 6 indicating smoke curtain failure

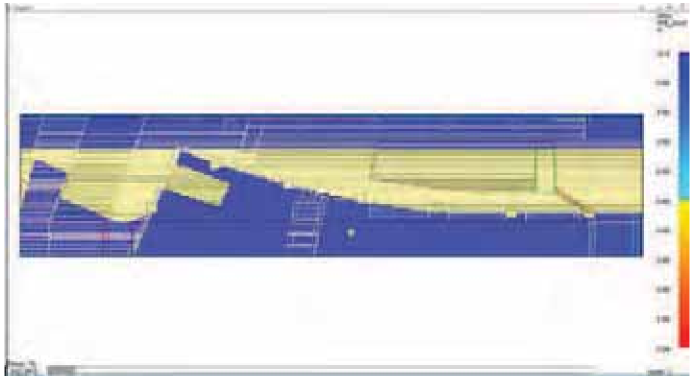
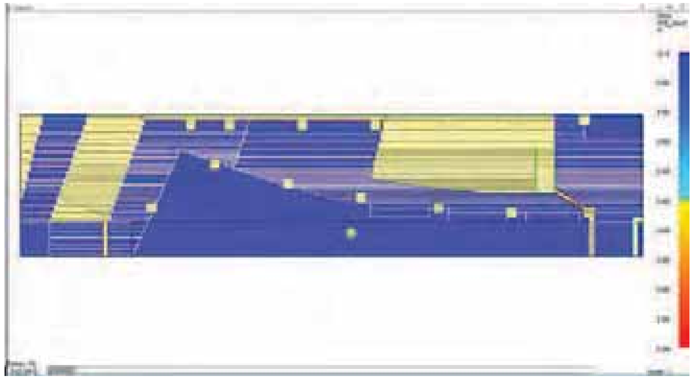
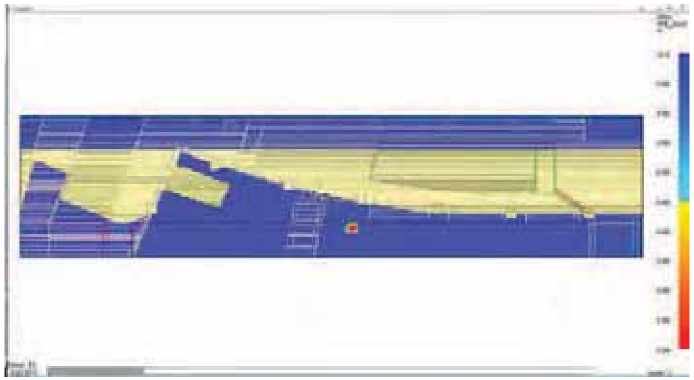
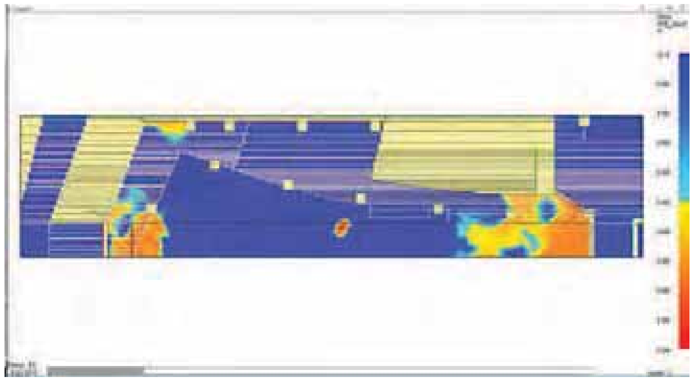
F.4 Scenario 1 results – Run06F[70]

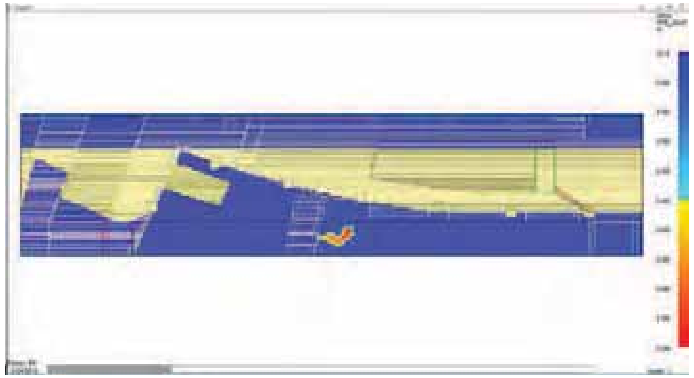
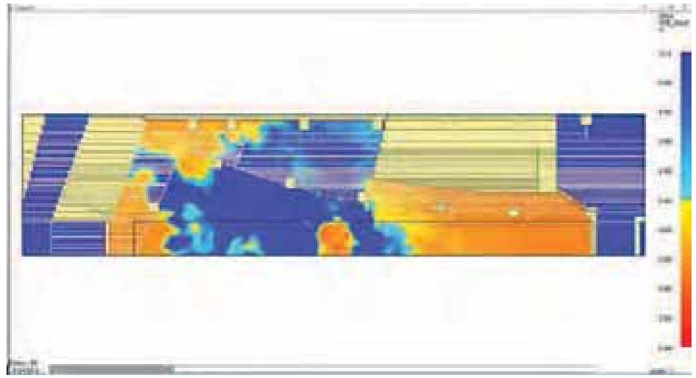
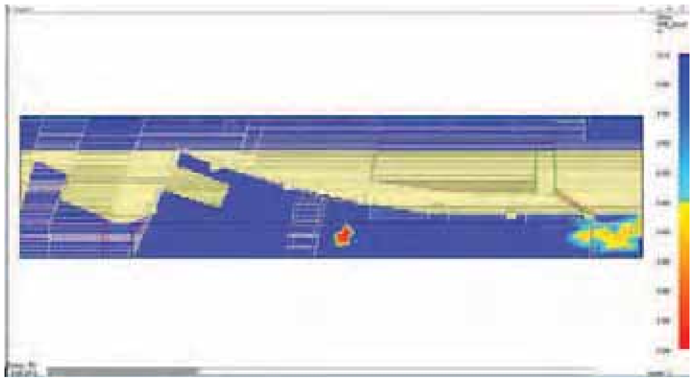
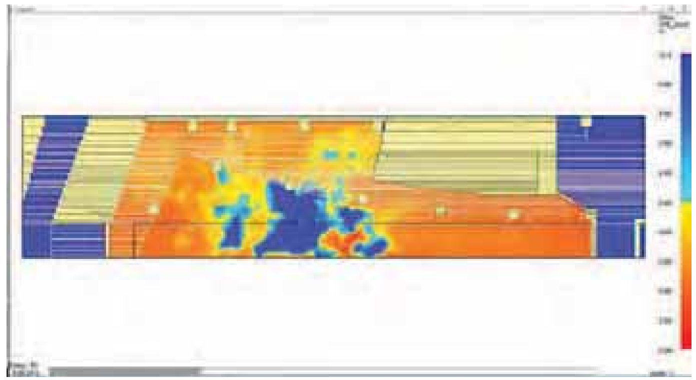
F.4.1 Smoke spread

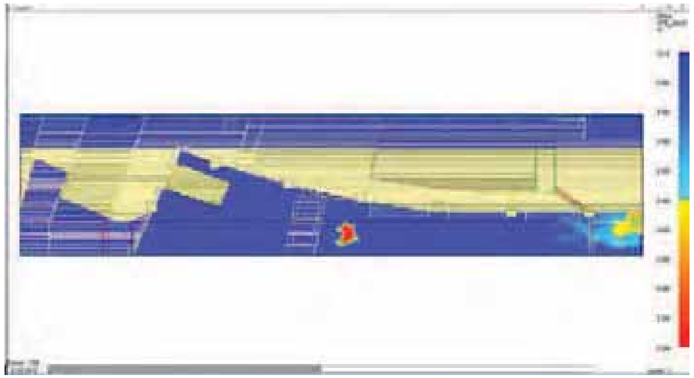
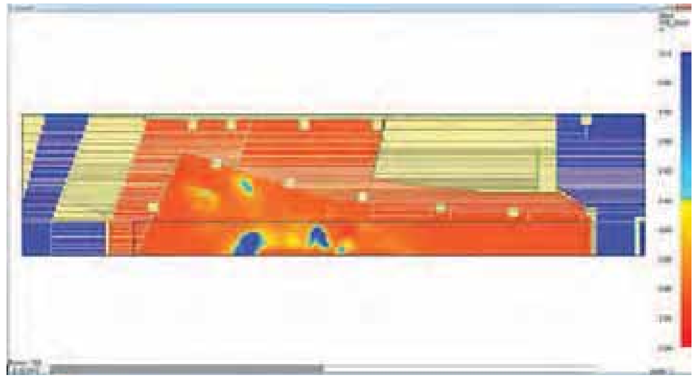
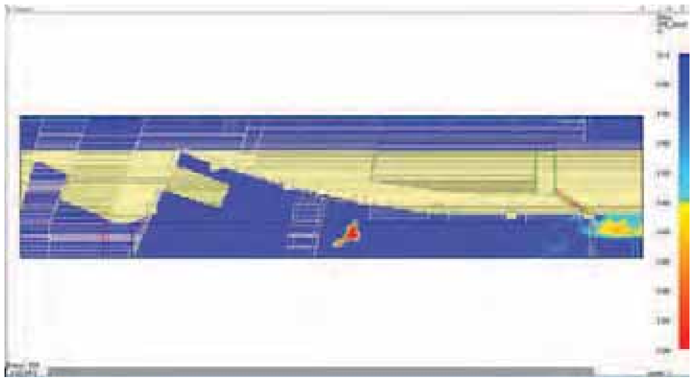
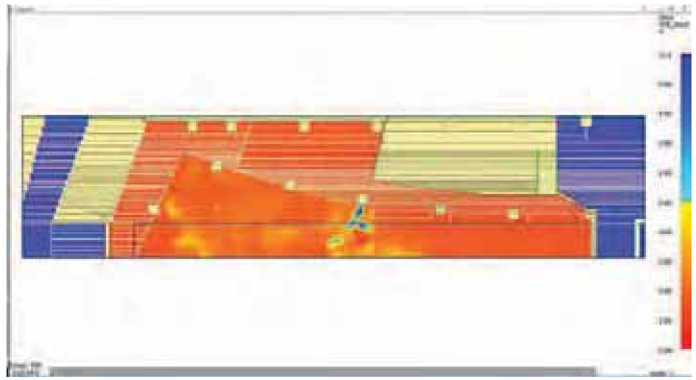
Timeline	Lower ground floor	Ground floor (heritage void)
1 minute The smoke detection system has activated initiating exhaust in the heritage void. A smoke plume rises and spreads along the underside of the heritage void roof. At this time occupants within the heritage void are expected to have received fire alarm and intrinsic fire cues.		
3 minutes Smoke has continued to spread on the underside of the heritage void roof and below the ceiling of the adjoining ground floor.		

[70] FDS data file – Run06F.fds

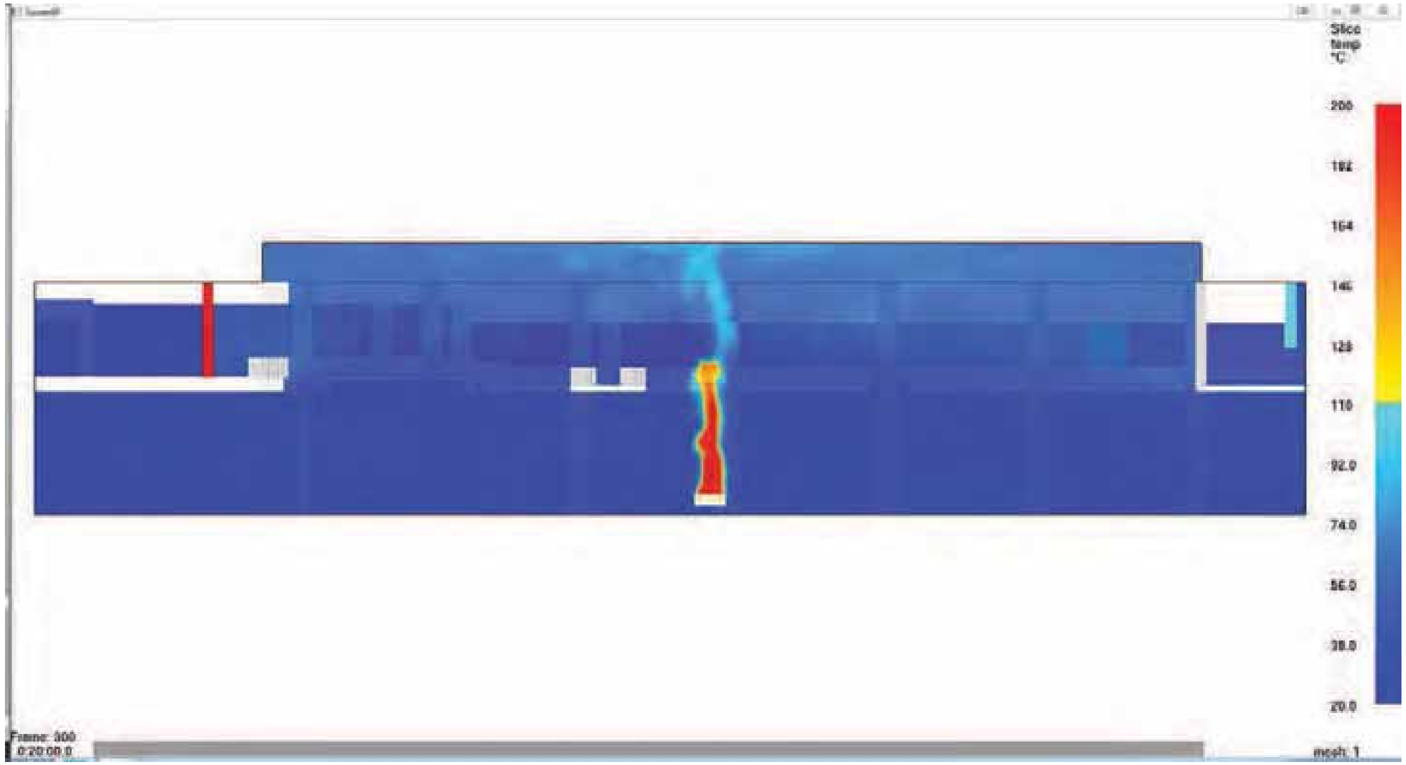
F.4.2 Visibility at 2m above floor level

<table>
<tr><th rowspan="2">Timeline</th><th>Lower ground floor</th><th>Ground floor (heritage void)</th></tr>
<tr><th colspan="2">The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.</th></tr>
<tr><td>1 minute
Visibility is in excess of 10m within the lower ground and ground floor of the heritage void.</td><td></td><td></td></tr>
<tr><td>3.5 minutes
Visibility within the void space on the ground floor has begun to drop below 10m. This is generally in non-trafficable portions of the ground floor – ie in the actual void.
Visibility on the lower ground floor remains in excess of 10m.</td><td></td><td></td></tr>
</table>

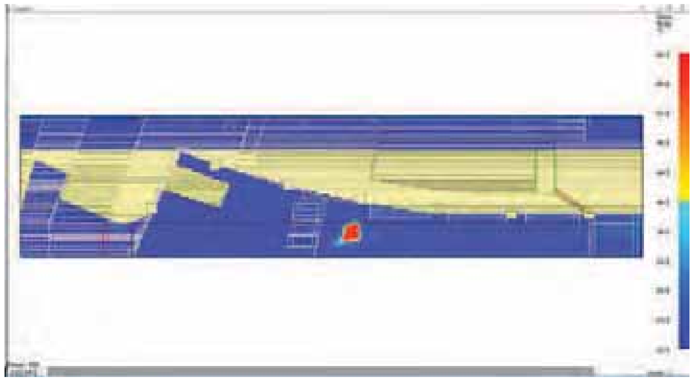
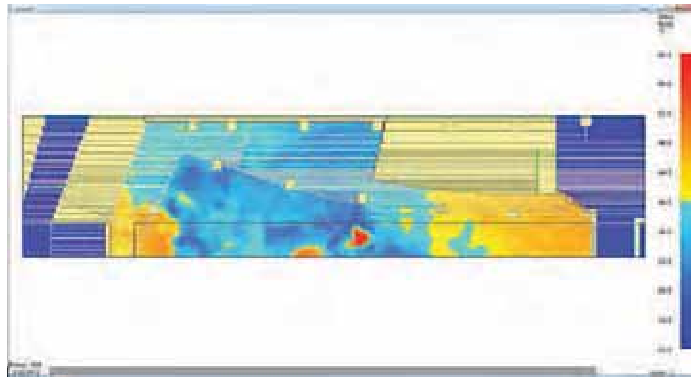
Timeline	Lower ground floor	Ground floor (heritage void)
4.5 minutes Visibility on the ground floor continues to worsen. The visibility around the bridge exit leading to Sussex Street is still in excess of 10m. Visibility on the lower ground floor remains in excess of 10m.		
5.5 minutes Visibility on the ground floor continues to worsen. Tenability within the ground floor is considered to be lost. Visibility on the lower ground floor remains in excess of 10m.		

Timeline	Lower ground floor	Ground floor (heritage void)
10 minutes Visibility on the lower ground floor remains in excess of 10m.		
20 minutes Visibility on the lower ground floor remains in excess of 10m.		

F.4.3 Temperature – section

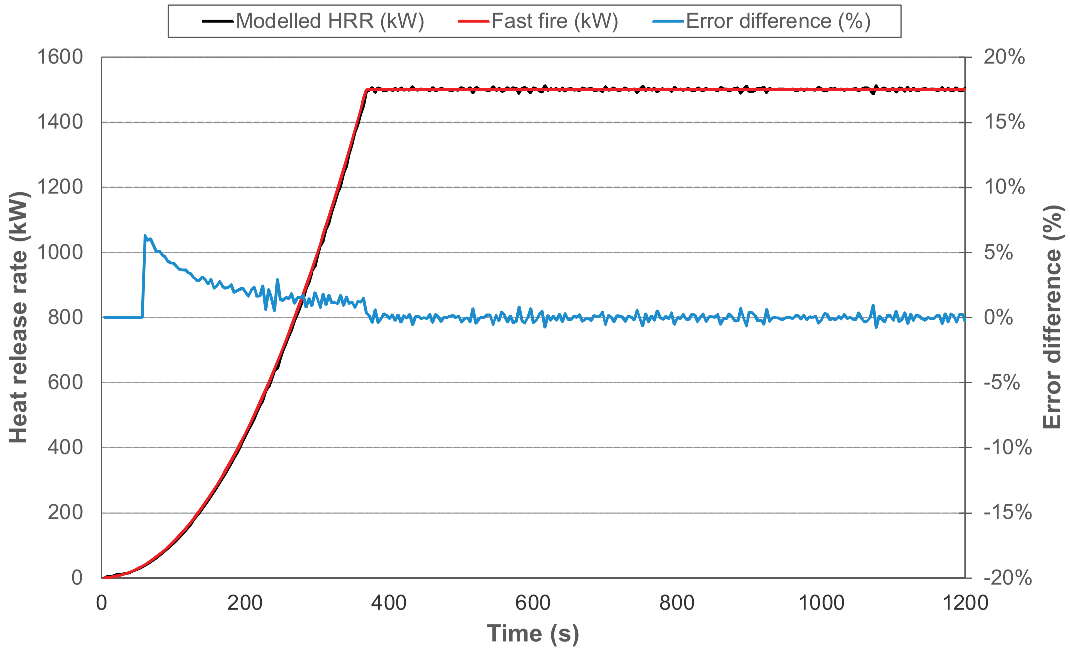
Timeline	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 200°C or greater, which corresponds to the limit for tenability for radiation.
20 minutes Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet.	

F.4.4 Temperature at 2m above floor level

Timeline	Lower ground floor	Ground floor (heritage void)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 60°C or greater, which is the limit for tenability.	
20 minutes The temperature throughout the lower ground floor and the ground floor is less than 60°C with the exception of the area of fire origin.		

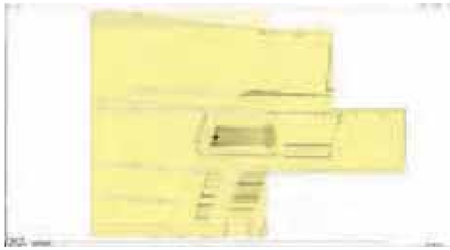
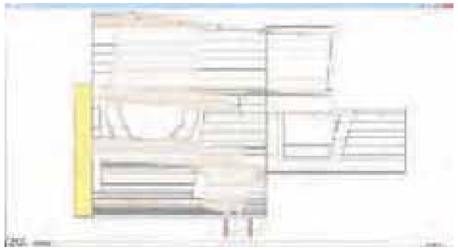
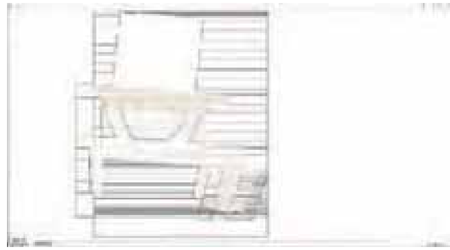
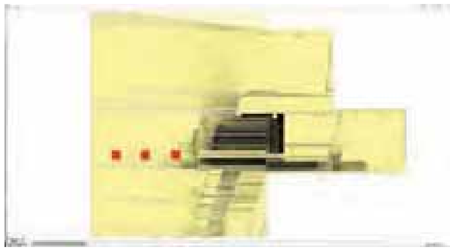
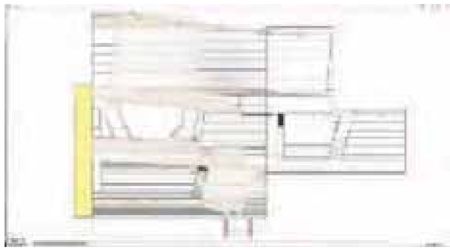
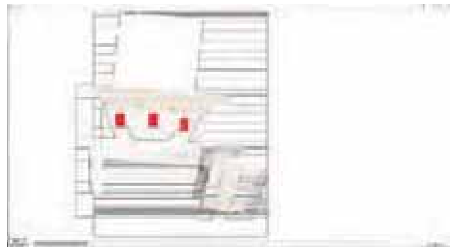
F.4.5 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



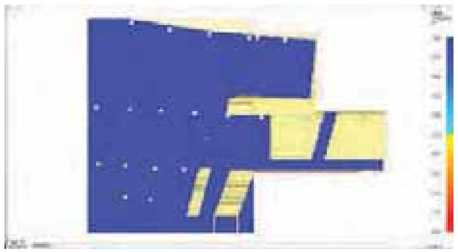
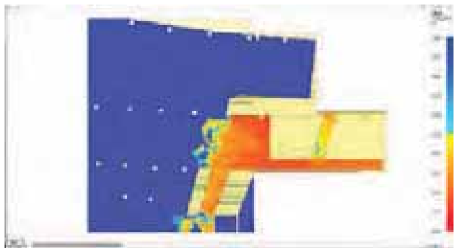
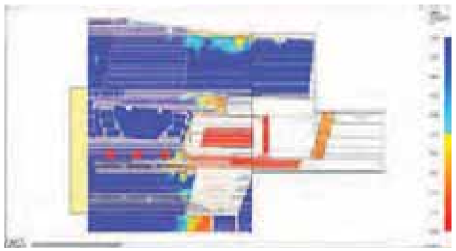
F.5 Scenario 2 results – Run02H[71]

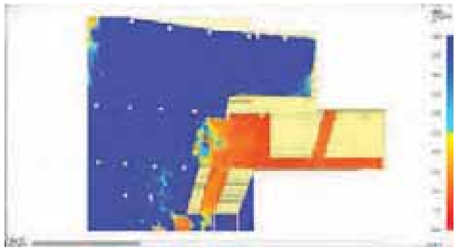
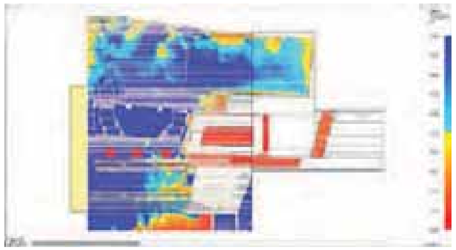
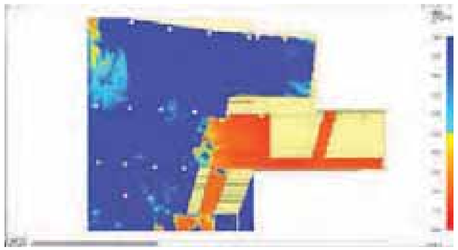
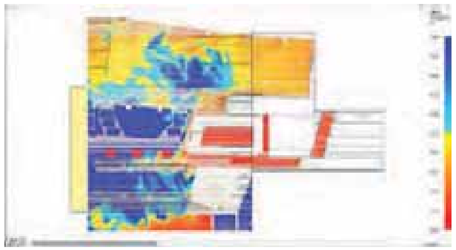
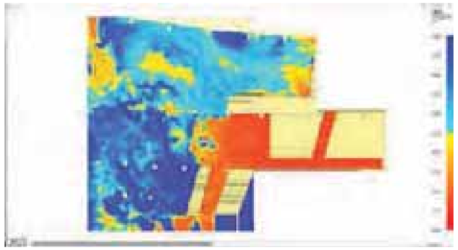
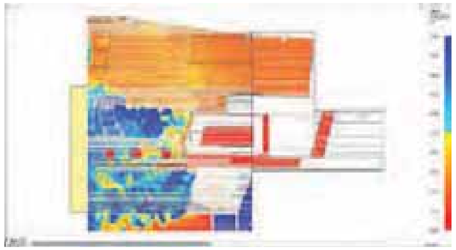
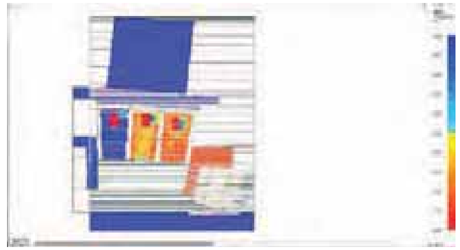
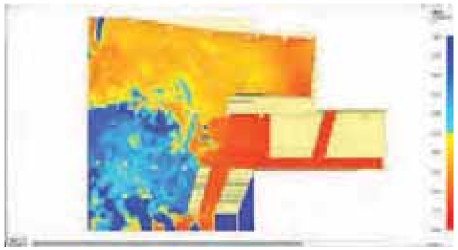
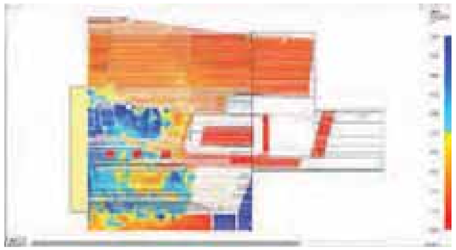
F.5.1 Smoke spread

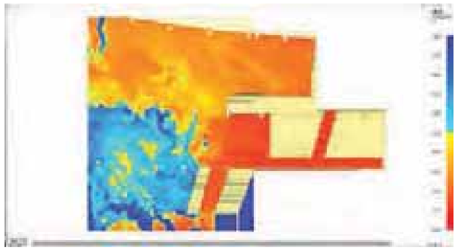
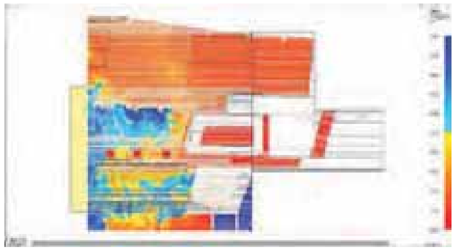
Timeline	Ground floor (south lobby)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
1 minute The smoke detection system has activated initiating exhaust on the ground and mezzanine floors. At this time occupants within the southern portion of the ground floor, including the all day dining restaurant and the southern pre-function area on the mezzanine floor are expected to have received fire alarm and intrinsic fire cues.			
3 minutes Smoke has continued to spread and covers a significant portion of the southern ground floor ceiling. The corridor leading to the northern portion of the building begins to fill with smoke.			

[71] FDS data file – Run02H.fds

F.5.2 Visibility at 2m above floor level

Timeline	Ground floor (south lobby)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
	The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.		
1 minute Visibility is in excess of 10m within the ground and mezzanine floor.			
5 minutes Visibility within the bar and the adjoin lift lobby area and corridor leading to the northern portion of the building has dropped below 10m. Occupants in the corridor are expected to have evacuated to the adjoining fire compartment. Visibility near the main feature stair on the mezzanine floor has dropped below 10m. The stair is considered to be blocked. Visibility is in excess of 10m in the remainder of the ground and mezzanine floor.			

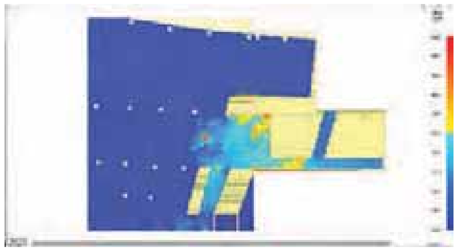
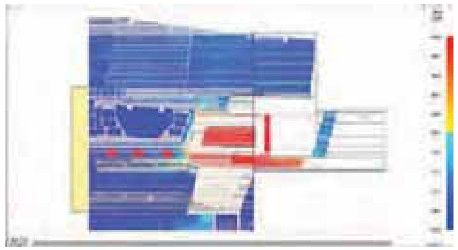
Timeline	Ground floor (south lobby)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
6 minutes Visibility within the all day dining restaurant begins to drop below 10m and remains below 10m in the area of fire origin. Visibility is in excess of 10m in the remainder of the ground and mezzanine floor.			
7 minutes Visibility within the restaurant continues to worsen. Tenability within the restaurant is considered to be lost. Visibility is in excess of 10m in the remainder of the ground and mezzanine floor.			
10 minutes Visibility within the ground floor begins to worsen and has reduced visibility but is considered tenable for wayfinding given the open nature of the lobby space, illuminated main exits and transient movement of the smoke.			
15 minutes Visibility within the ground floor has reduced visibility but is considered tenable for wayfinding given the open nature of the lobby space, illuminated main exits and transient movement of the smoke.			

Timeline	Ground floor (south lobby)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
20 minutes Visibility within the ground floor has reduced visibility but is considered tenable for wayfinding given the open nature of the lobby space, illuminated main exits and transient movement of the smoke.			

F.5.3 Temperature – section

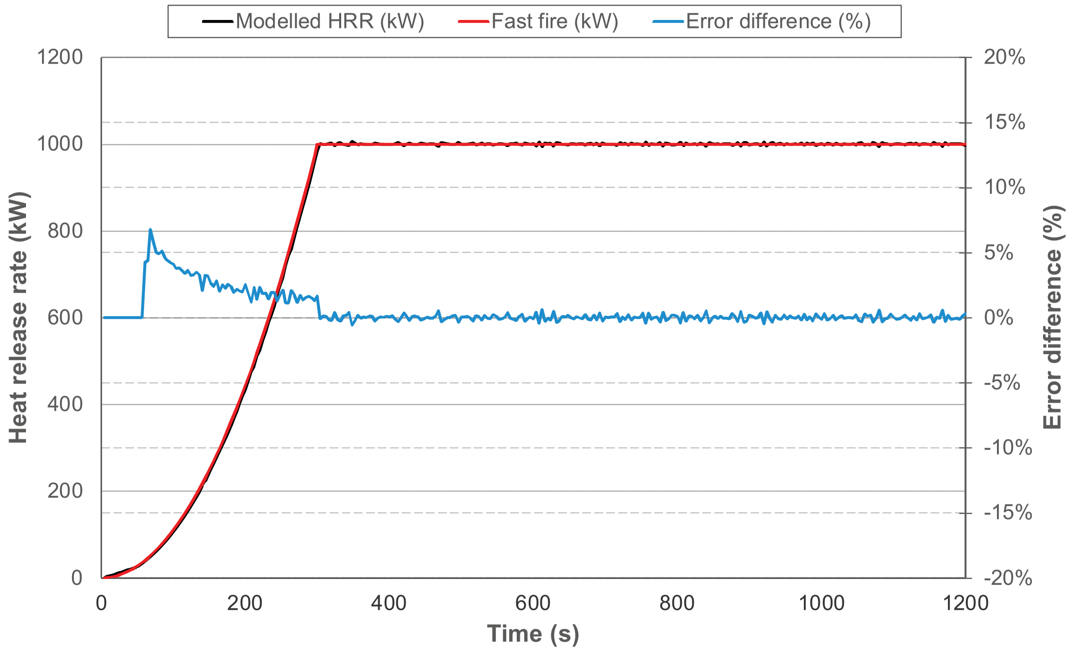
<table>
<tr><th>Timeline</th><th>The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 200°C or greater, which corresponds to the limit for tenability for radiation.</th></tr>
<tr><td>20 minutes
Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet</td><td></td></tr>
</table>

F.5.4 Temperature at 2m above floor level

Timeline	Ground floor (south lobby)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 60°C or greater, which is the limit for tenability.		
20 minutes The temperature throughout the ground floor and mezzanine floor at 2m above floor level is less than 60°C with the exception of the area of fire origin.			

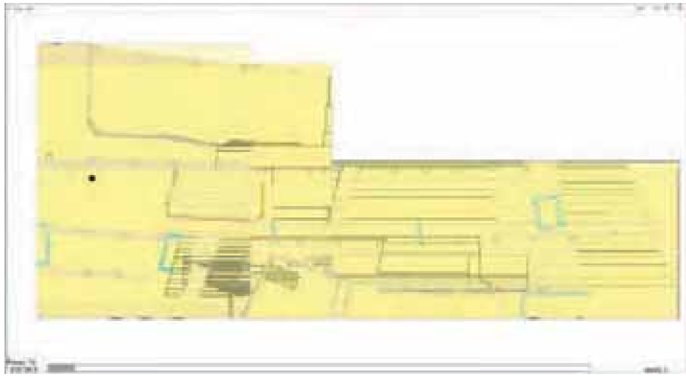
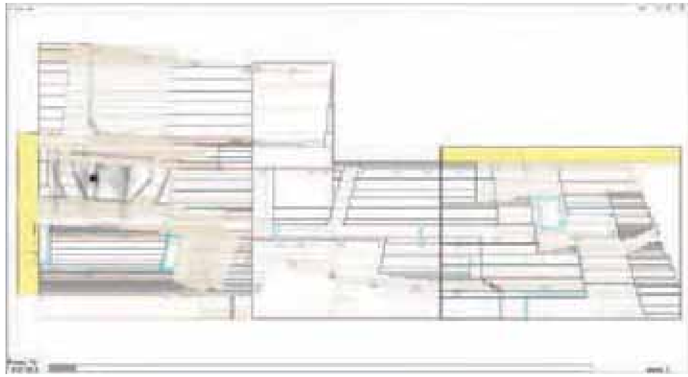
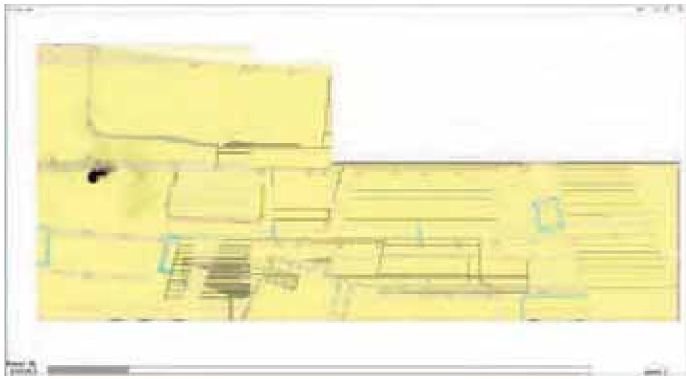
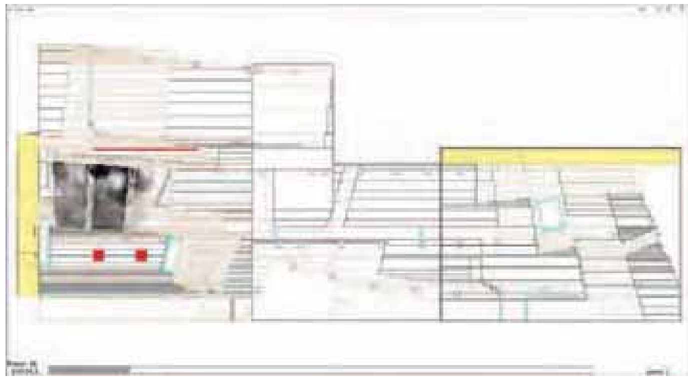
F.5.5 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



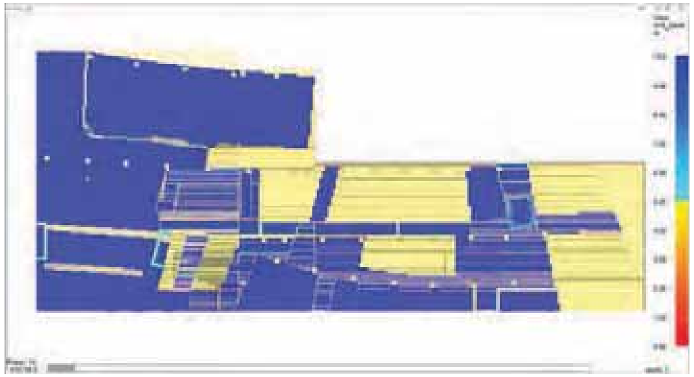
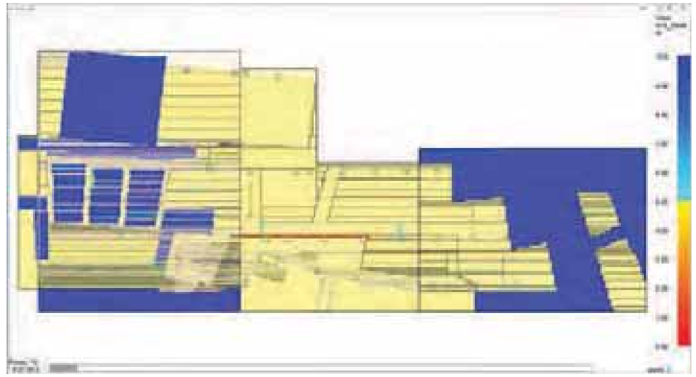
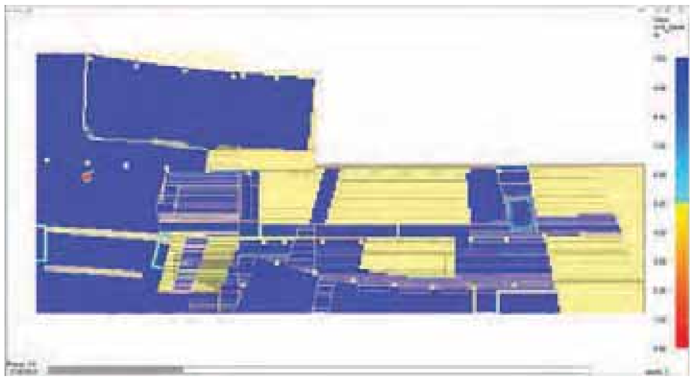
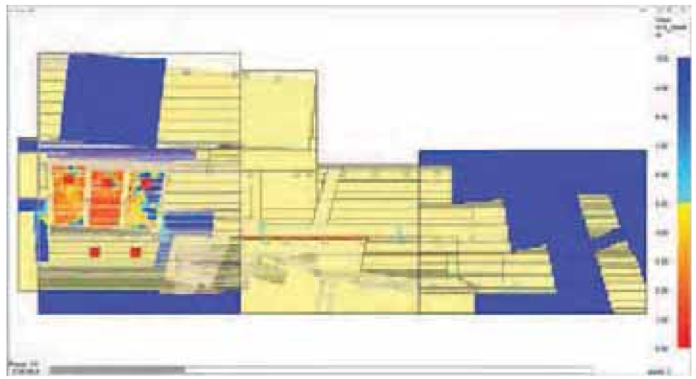
F.6 Scenario 3 results – Run01B[72]

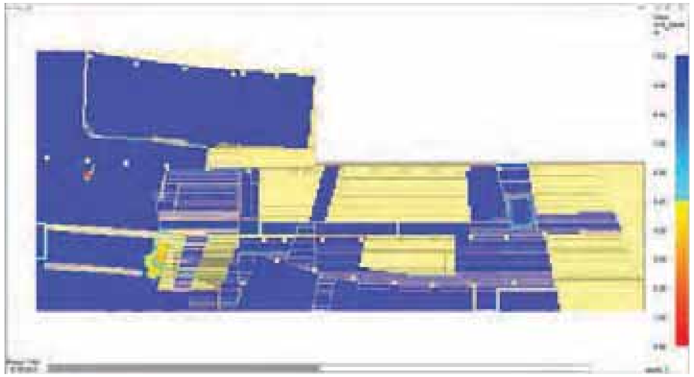
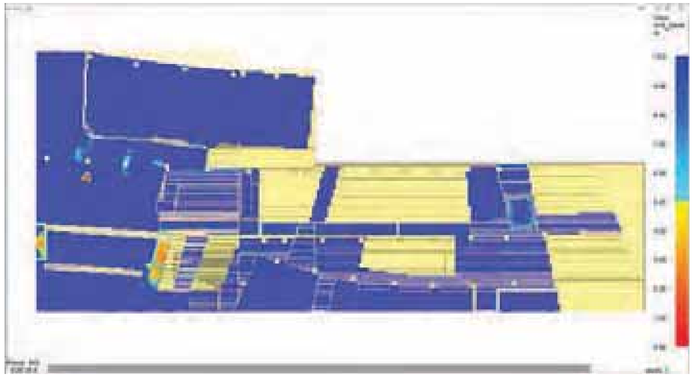
F.6.1 Smoke spread

Timeline	Ground floor (south)	Mezzanine (south pre-function)
1 minute The smoke detection system has activated initiating exhaust on the ground and mezzanine floors. At this time occupants within the southern portion of the ground floor, including the all day dining restaurant and the southern pre-function area on the mezzanine floor are expected to have received fire alarm and intrinsic fire cues.		
3 minutes Smoke has continued to spread and covers a significant portion of the mezzanine ceiling.		

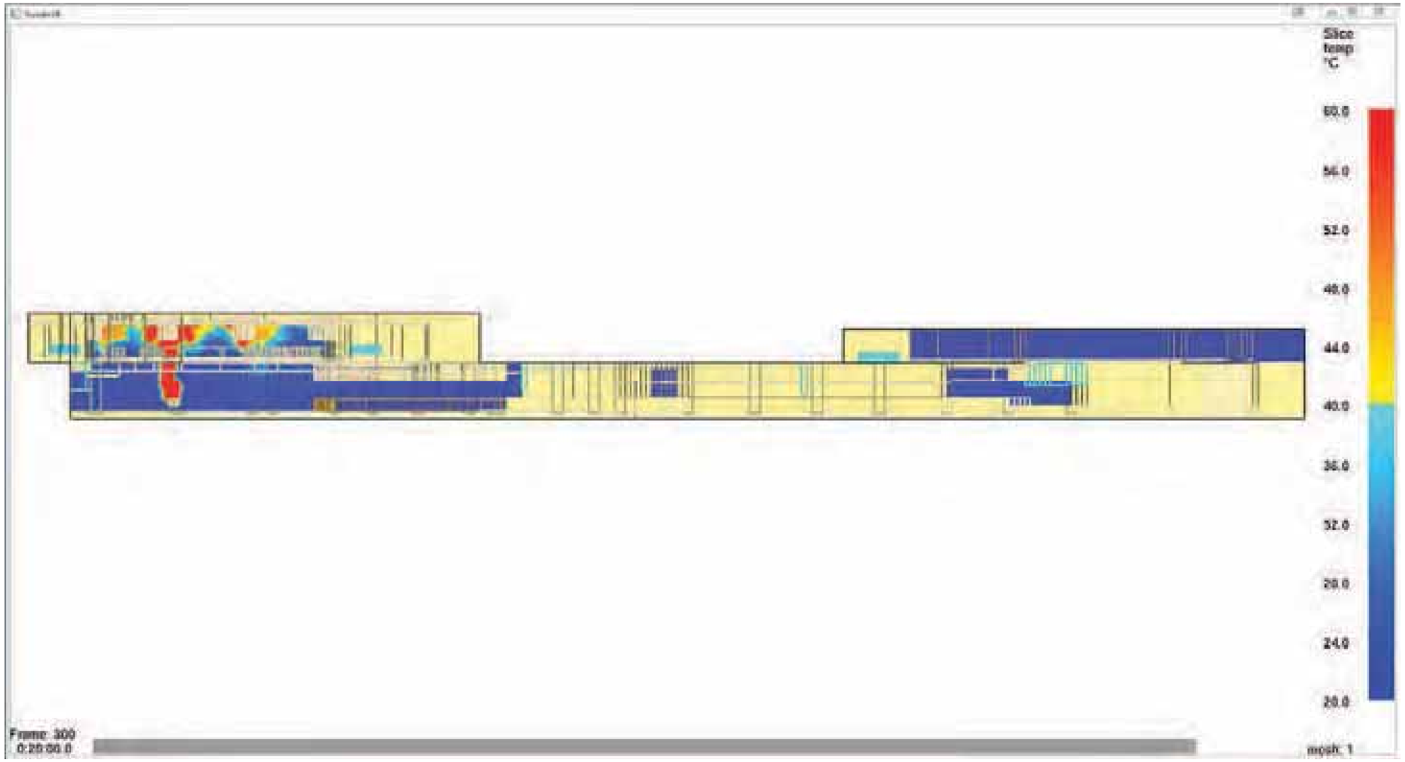
[72] FDS data file – Run01B.fds

F.6.2 Visibility at 2m above floor level

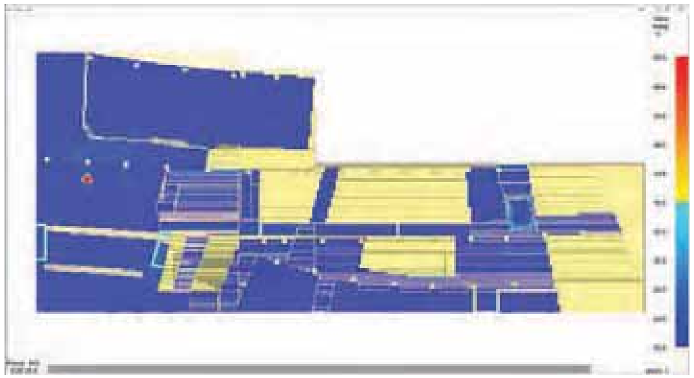
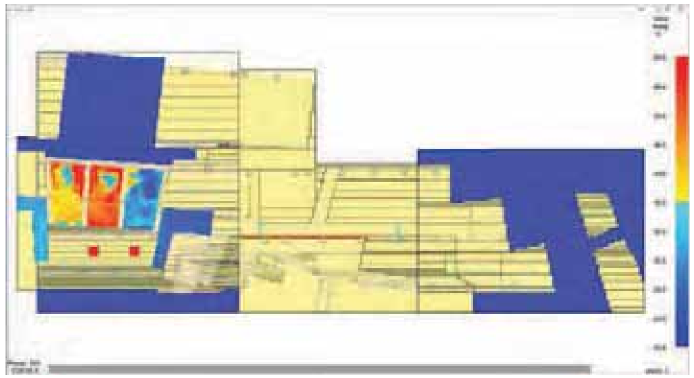
Timeline	Ground floor (south)	Mezzanine (south pre-function)
	The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.	
1 minute Visibility is in excess of 10m within the ground and mezzanine floor.		
5 minutes Visibility within the mezzanine floor directly above the void has dropped below 10m. The main feature stair is considered to be blocked. Visibility is in excess of 10m within the ground floor and the remainder of the mezzanine floor.		

Timeline	Ground floor (south)	Mezzanine (south pre-function)
10 minutes Smoke is contained within the mezzanine void area. Visibility is in excess of 10m within the ground floor and the remainder of the mezzanine floor.		
20 minutes Smoke is contained within the mezzanine void area. Visibility is in excess of 10m within the ground floor and the remainder of the mezzanine floor.		

F.6.3 Temperature – section

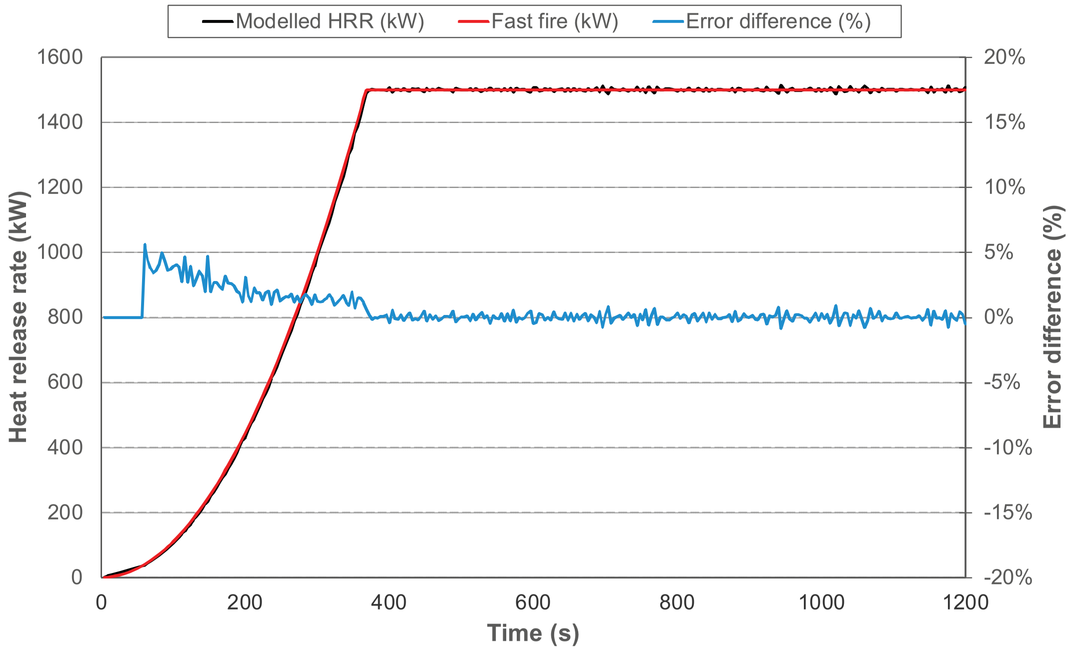
Timeline	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 200°C or greater, which corresponds to the limit for tenability for radiation.
20 minutes Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet.	

F.6.4 Temperature at 2m above floor level

Timeline	Ground floor (south)	Mezzanine (south pre-function)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of approximately 60°C or greater, which is the limit for tenability.	
20 minutes The temperature throughout the ground floor and mezzanine floor at 2m above floor level is less than 60°C with the exception of the area of the fire plume and ceiling jet. Where the temperature exceeds 60°C on the mezzanine floor, this is within the void space.		

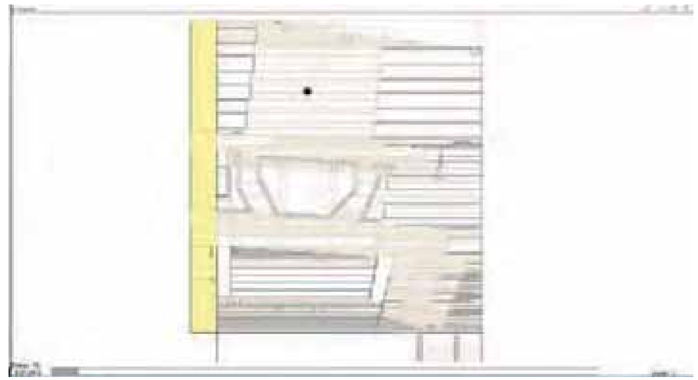
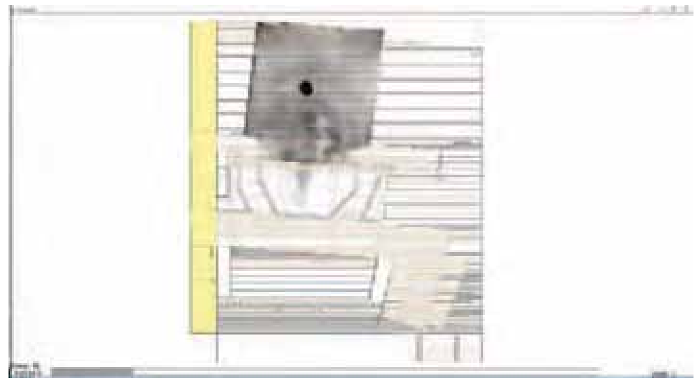
F.6.5 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



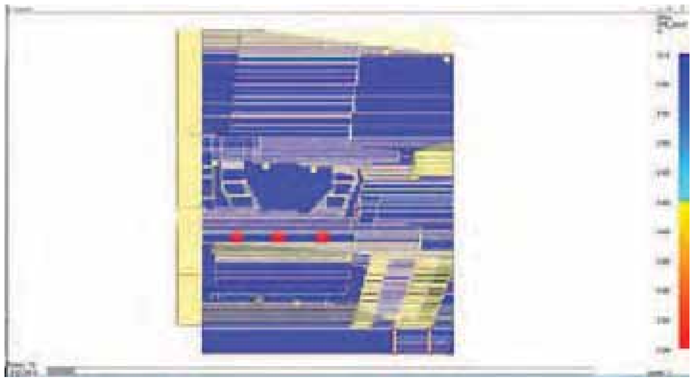
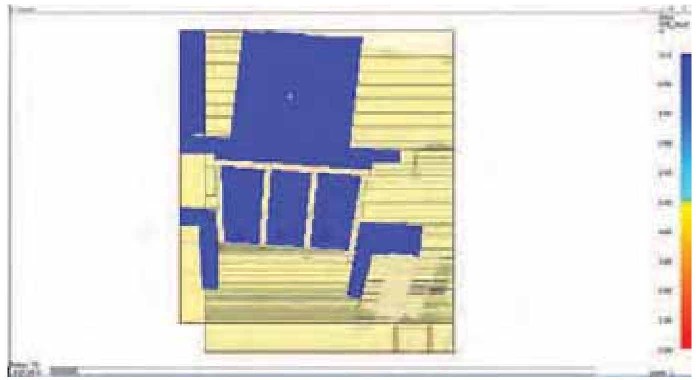
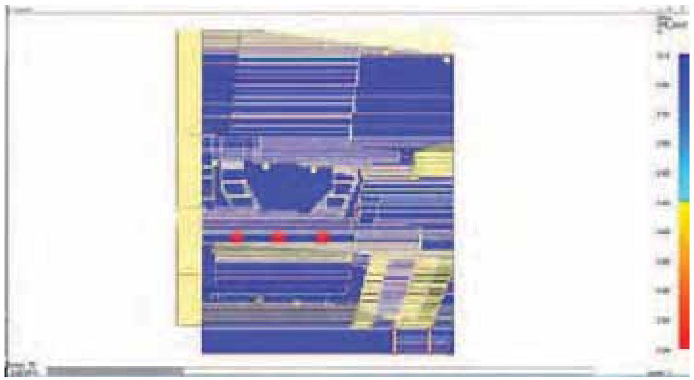
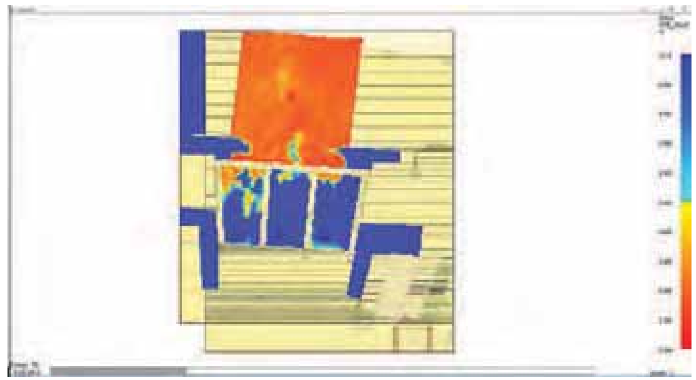
F.7 Scenario 4 results – Run04C[73]

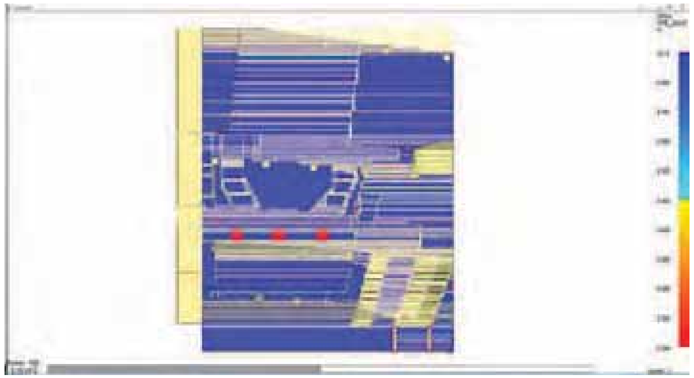
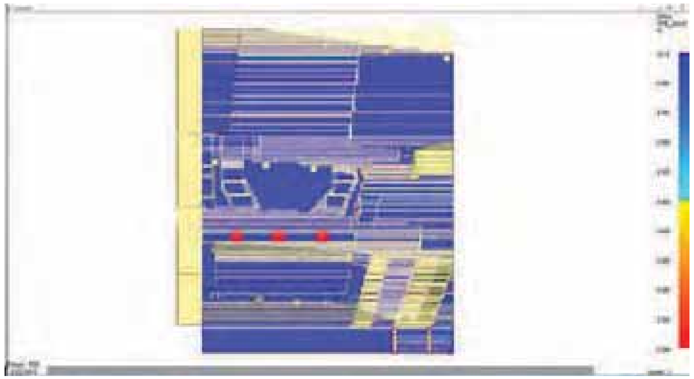
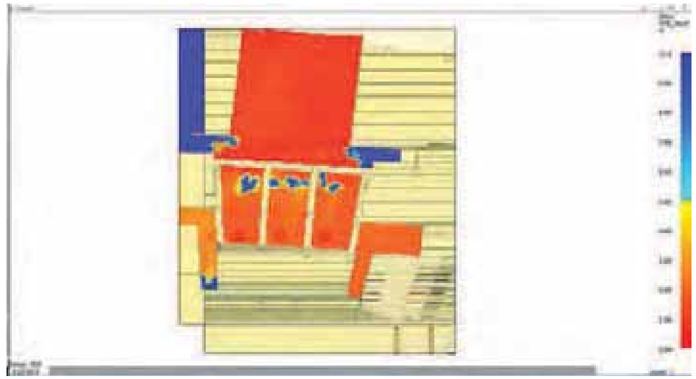
F.7.1 Smoke spread

Timeline	Ground floor (south)	Mezzanine (south pre-function)
1 minute The smoke detection system has activated initiating exhaust on the ground and mezzanine floors. At this time occupants within the southern pre-function area on the mezzanine floor are expected to have received fire alarm and intrinsic fire cues. Occupants in the southern portion of the ground floor are expected to have receive fire alarm cues.		
3 minutes Smoke has continued to spread and covers a significant portion of the mezzanine pre-function ceiling.		

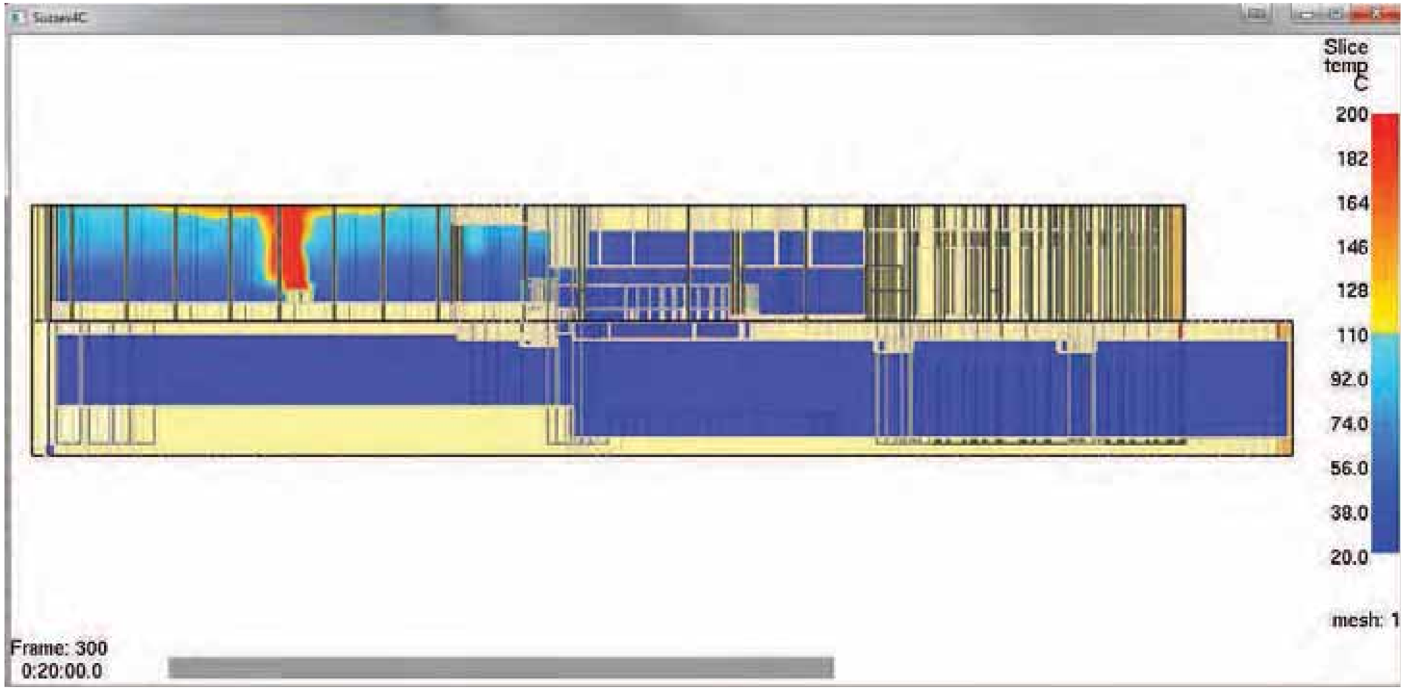
[73] FDS data file – Run04C.fds

F.7.2 Visibility at 2m above floor level

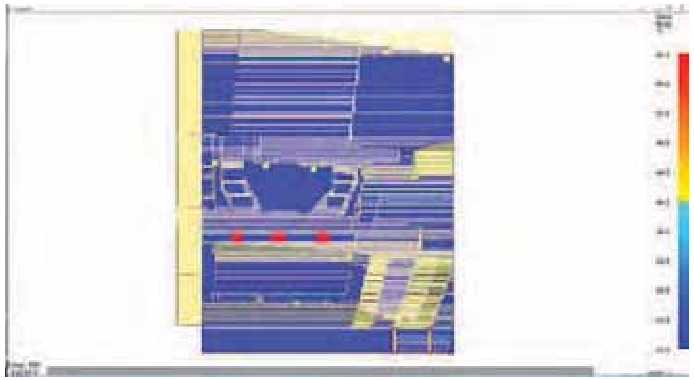
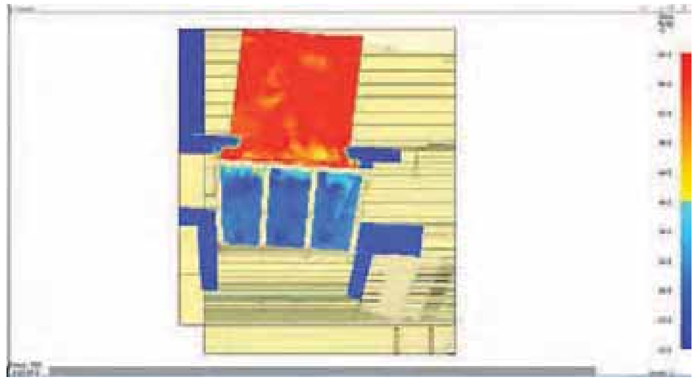
Timeline	Ground floor (south)	Mezzanine (south pre-function)
	The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.	
1 minute Visibility is in excess of 10m within the ground and mezzanine floor.		
5 minutes Visibility in the immediate region around the fire in the southern pre-function area has dropped below 5m. However occupants in this region are expected to have moved away from this area in the early stages of fire growth and are expected to be queuing at the horizontal exits to the adjoining fire compartments. Visibility in the queuing area directly adjacent to the horizontal exits is in excess of 10m. Visibility is in excess of 10m within the ground floor.		

Timeline	Ground floor (south)	Mezzanine (south pre-function)
10 minutes Visibility in the queuing area directly adjacent to the horizontal exits from the southern pre-function area on the mezzanine floor remains in excess of 10m. Visibility is in excess of 10m within the ground floor.		
20 minutes Visibility in the queuing area directly adjacent to the horizontal exits from the southern pre-function area on the mezzanine floor remains in excess of 10m Visibility is in excess of 10m within the ground floor.		

F.7.3 Temperature – section

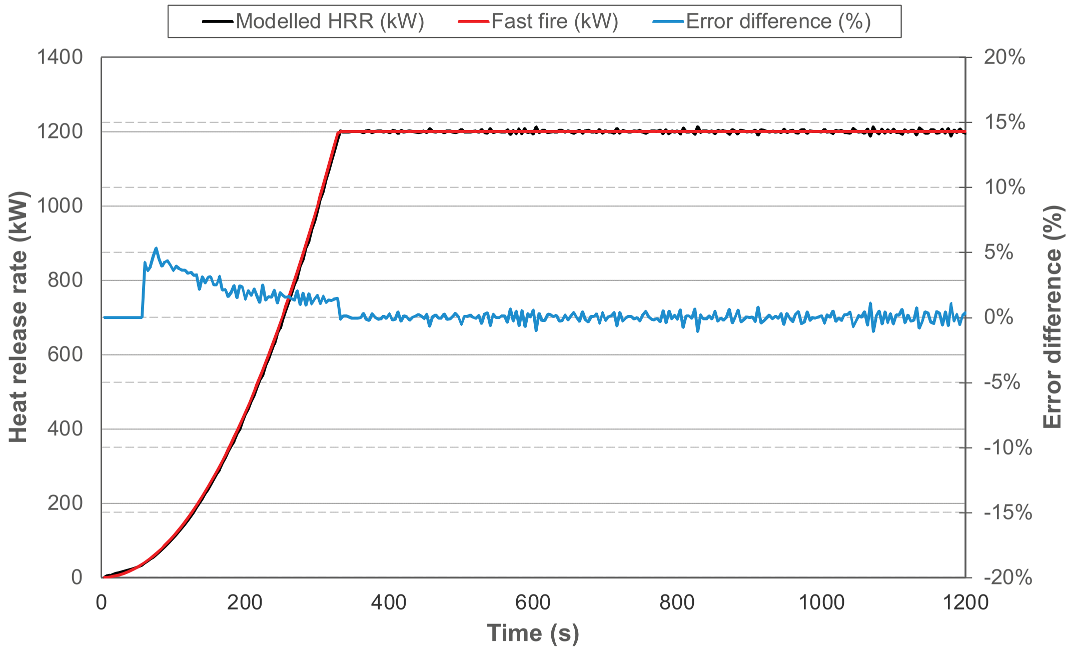
Timeline	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 200°C or greater, which corresponds to the limit for tenability for radiation.
20 minutes Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet.	

F.7.4 Temperature at 2m above floor level

Timeline	Ground floor (south)	Mezzanine (south pre-function)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 60°C or greater, which is the limit for tenability.	
20 minutes The temperature throughout the ground floor and mezzanine floor at 2m above floor level is less than 60°C with the exception of the area of the fire plume and ceiling jet.		

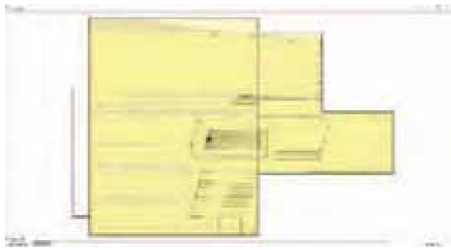
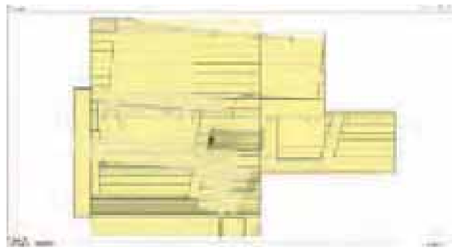
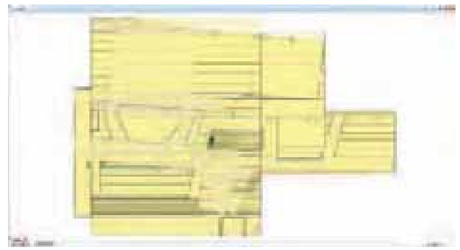
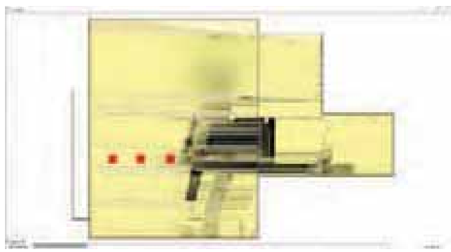
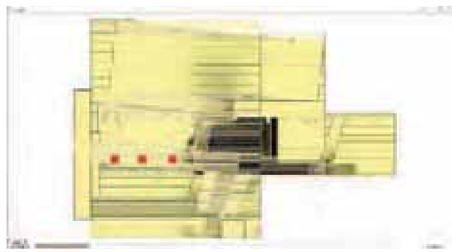
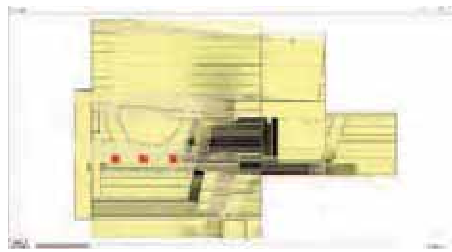
F.7.5 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



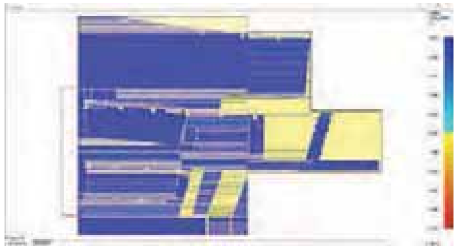
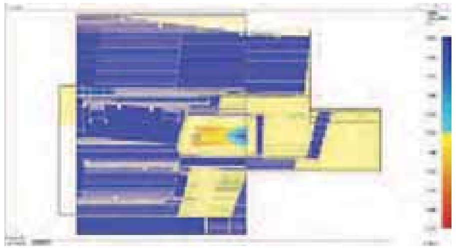
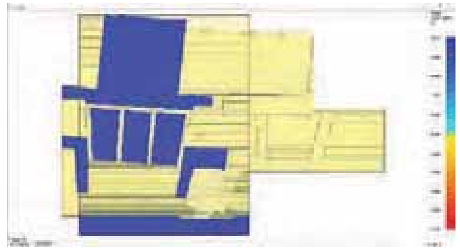
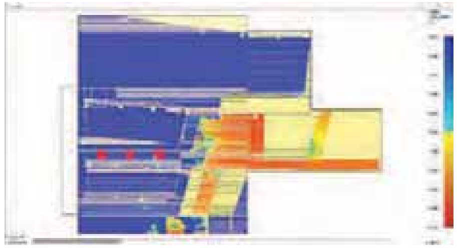
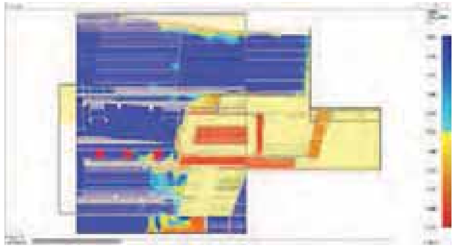
F.8 Scenario 5 results – Run09A [74]

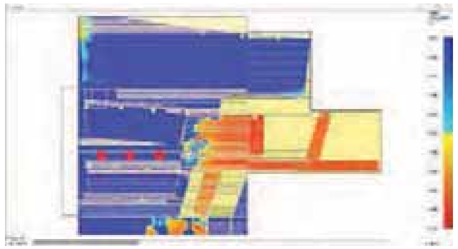
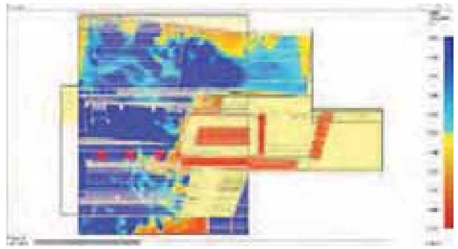
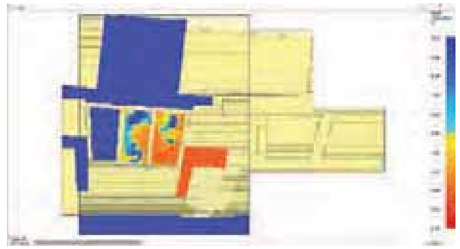
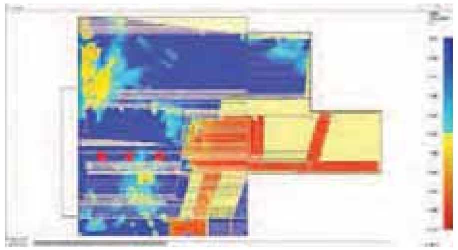
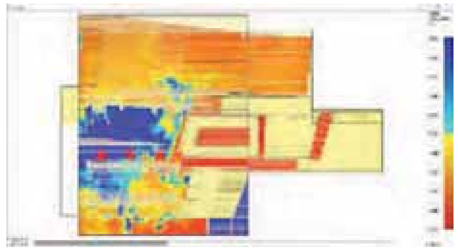
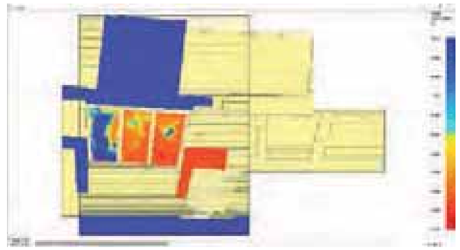
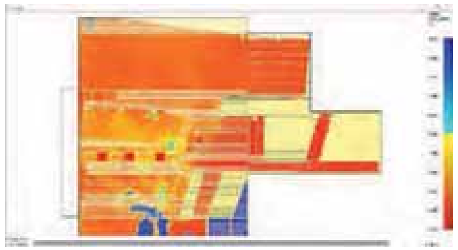
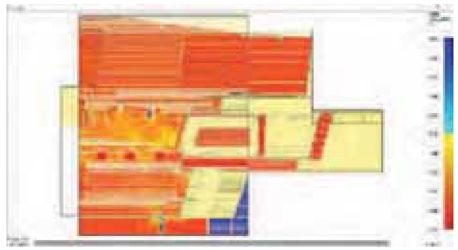
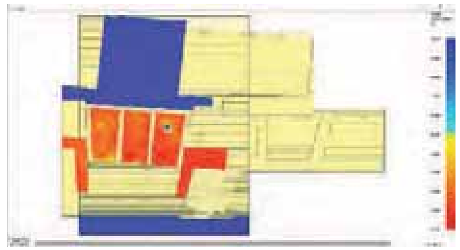
F.8.1 Smoke spread

Timeline	Ground floor (south)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
1 minute The smoke detection system has activated initiating exhaust on the ground and mezzanine floors. At this time occupants within the southern portion of the ground floor, including the all day dining restaurant and the southern pre-function area on the mezzanine floor are expected to have received fire alarm and intrinsic fire cues.			
3 minutes Smoke has continued to spread and covers a significant portion of the southern ground floor ceiling. The corridor leading to the northern portion of the building begins to fill with smoke.			

[74] FDS data file – Run09A.fds

F.8.2 Visibility at 2m above floor level

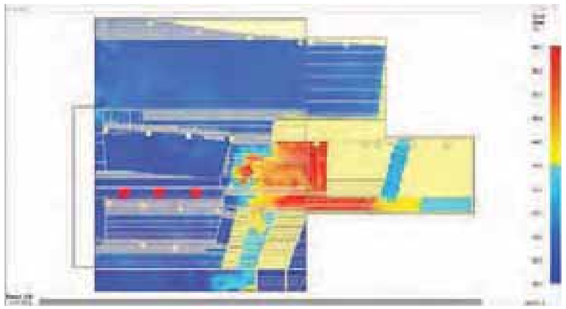
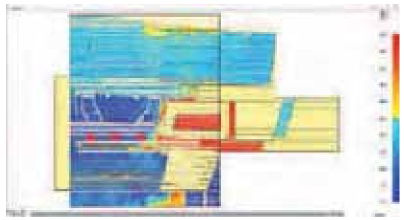
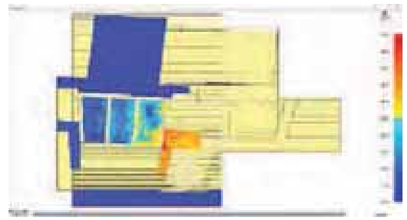
Timeline	Ground floor (south)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
	The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.		
1 minute Visibility is in excess of 10m within the ground and mezzanine floor.			
5 minutes Visibility within the bar and the adjoin lift lobby area and corridor leading to the northern portion of the building has dropped below 10m. Occupants in the corridor are expected to have evacuated to the adjoining fire compartment. Visibility near the main feature stair on the mezzanine floor has dropped below 10m. The stair is considered to be blocked. Visibility is in excess of 10m in the remainder of the ground and mezzanine floor.			

Timeline	Ground floor (south)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
6 minutes Visibility within the all day dining restaurant begins to drop below 10m and remains below 10m in the area of fire origin. Visibility is in excess of 10m in the remainder of the ground and mezzanine floor.			
7.5 minutes Visibility within the restaurant and the ground floor continues to worsen. Visibility within the ground floor and restaurant is considered to be lost.			
20 minutes Visibility within the ground floor and restaurant is considered to be lost.			

F.8.3 Temperature – section

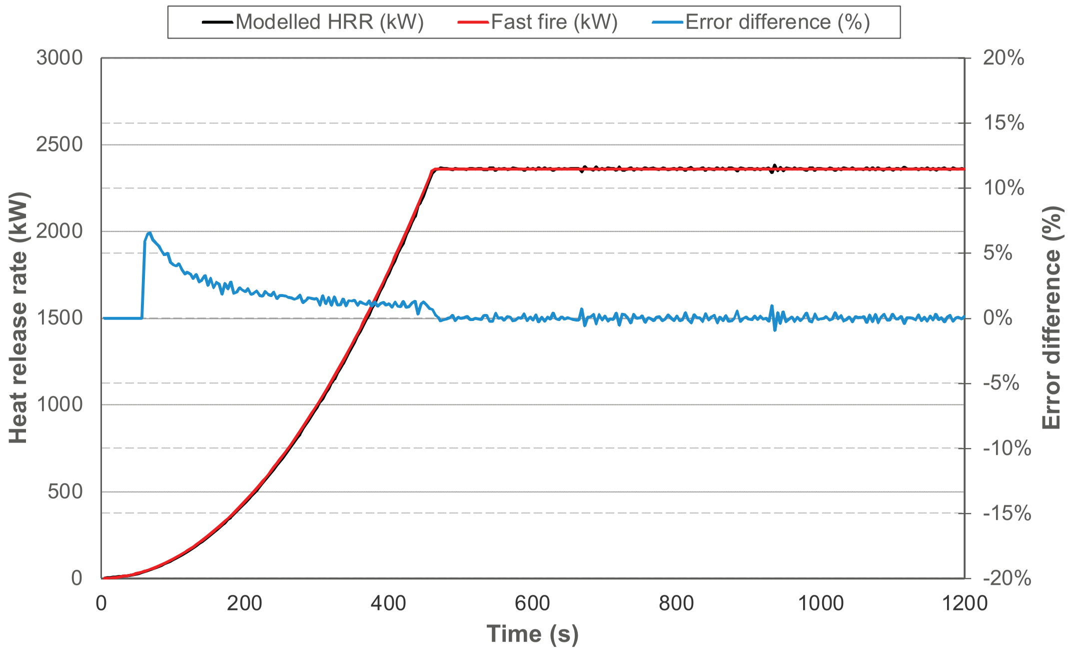
Timeline	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of approximately 200°C, which corresponds to the limit for tenability for radiation.
20 minutes Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet	

F.8.4 Temperature at 2m above floor level

Timeline	Ground floor (south)	Ground floor (restaurant)	Mezzanine floor (south pre-function)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 60°C or greater, which is the limit for tenability.		
20 minutes The temperature throughout the ground floor and mezzanine floor at 2m above floor level is less than 60°C with the exception of the area of fire origin.			

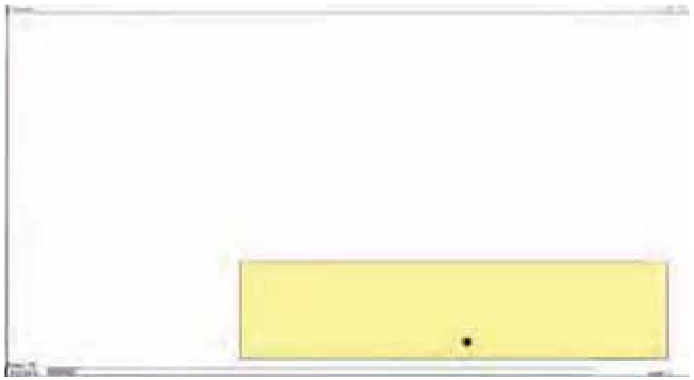
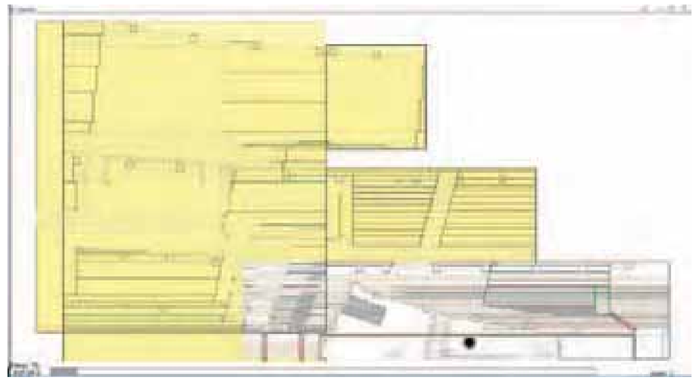
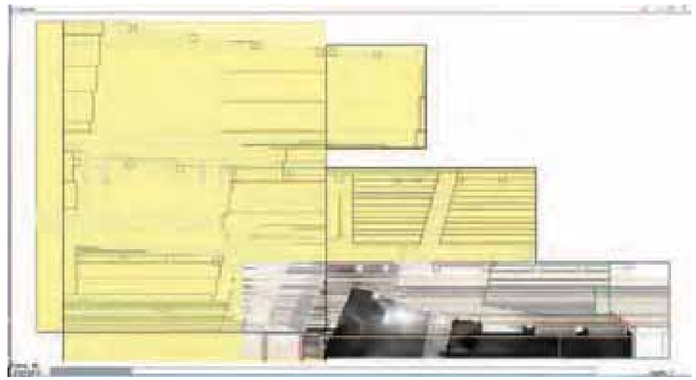
F.9 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



F.10 Scenario 6 results – Run08A[75]

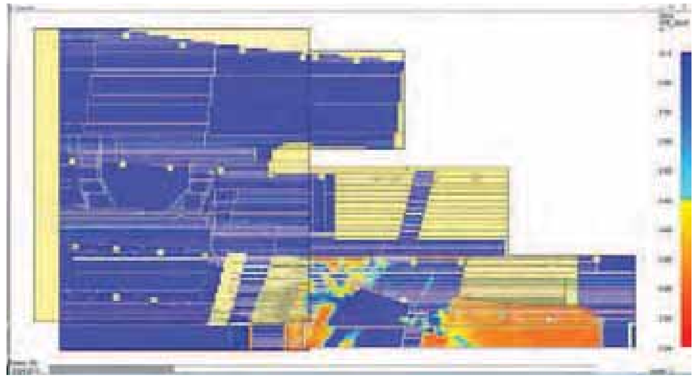
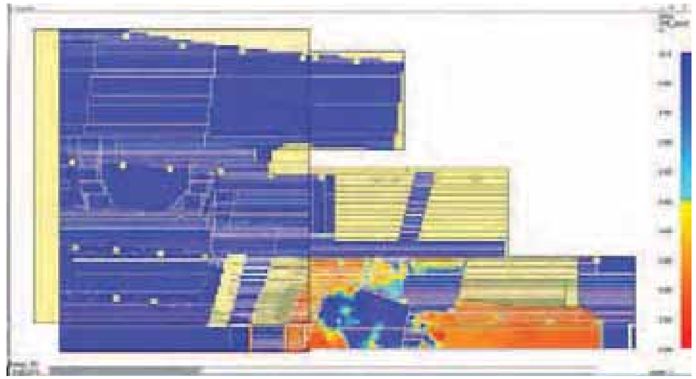
F.10.1 Smoke spread

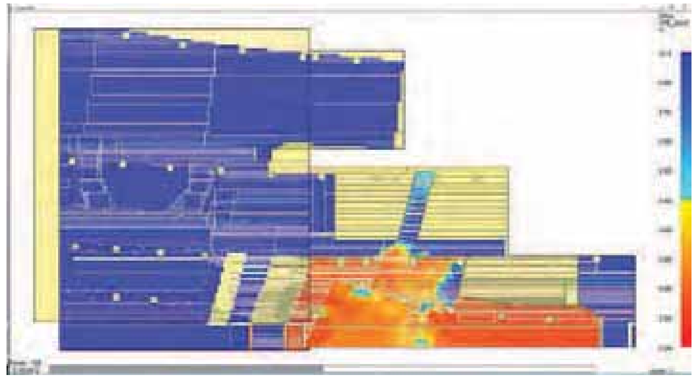
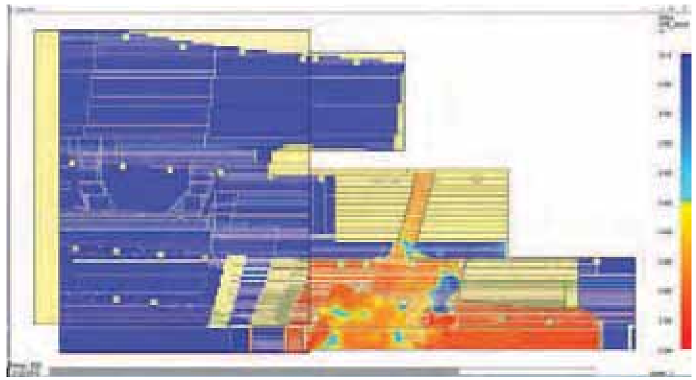
Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
1 minute The smoke detection system has activated initiating exhaust in the heritage void. A smoke plume rises and spreads along the underside of the heritage void roof. At this time occupants within the heritage void are expected to have received fire alarm and intrinsic fire cues.		
3 minutes Smoke has continued to spread on the underside of the heritage void roof and below the ceiling of the adjoining ground floor.		

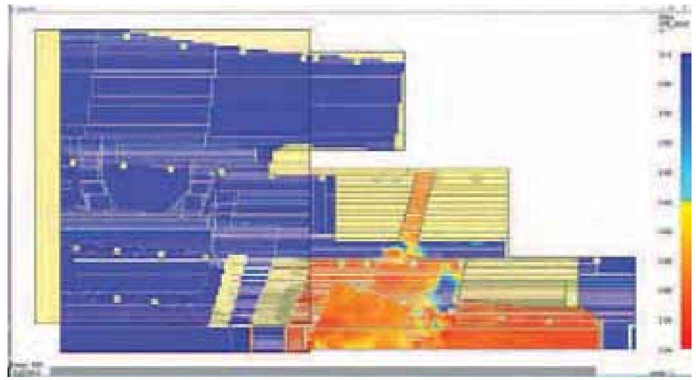
[75] FDS data file – Run08A.fds

F.10.2 Visibility at 2m above floor level

Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
	The colour blue indicates visibility exceeding 10m to non-illuminated walls and obstructions. A reduced visibility of 5m (yellow colour) is considered acceptable in small enclosures or near exits with illuminated signage. Other colours indicate a visibility of less than 10m.	
1 minute Visibility is in excess of 10m within the lower ground and ground floor of the heritage void.		
3.5 minutes Visibility within the void space on the ground floor has begun to drop below 10m. This is generally in non-trafficable portions of the ground floor – ie in the actual void. Visibility on the lower ground floor and in the adjoining ground floor smoke compartment remains in excess of 10m.		

Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
4.5 minutes Visibility on the ground floor continues to worsen. The visibility around the bridge exit leading to Sussex Street is still in excess of 10m. Visibility on the lower ground floor and in the adjoining ground floor smoke compartment remains in excess of 10m.		
5.5 minutes Visibility on the ground floor continues to worsen. Tenability within the ground floor is considered to be lost. Visibility on the lower ground floor and in the adjoining ground floor smoke compartment remains in excess of 10m.		

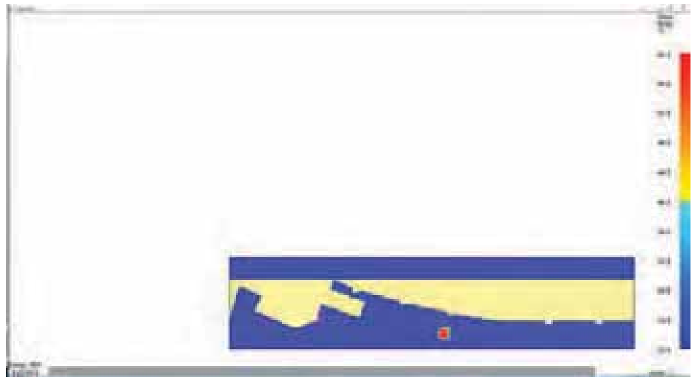
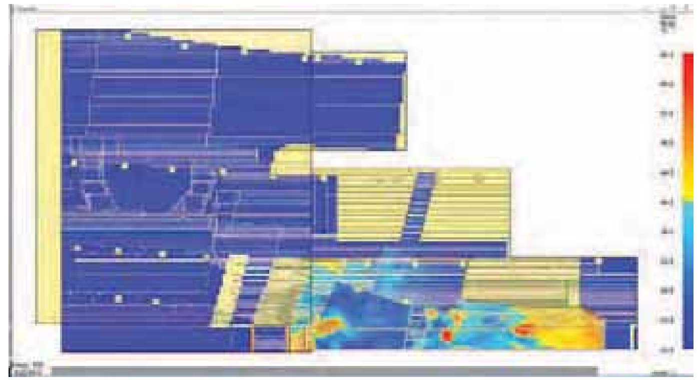
Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
10 minutes Visibility in the corridor adjacent to the smoke curtains begins to drop below 10m however visibility in the majority of the southern ground floor remains in excess of 10m. Visibility on the lower ground floor remains in excess of 10m.		
15 minutes Visibility in the corridor adjacent to the smoke curtains is considered to be lost however visibility in the majority of the southern ground floor remains in excess of 10m. Visibility on the lower ground floor remains in excess of 10m.		

Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
20 minutes Visibility in the corridor adjacent to the smoke curtains is considered to be lost however visibility in the majority of the southern ground floor remains in excess of 10m. Visibility on the lower ground floor remains in excess of 10m.		

F.10.3 Temperature – section

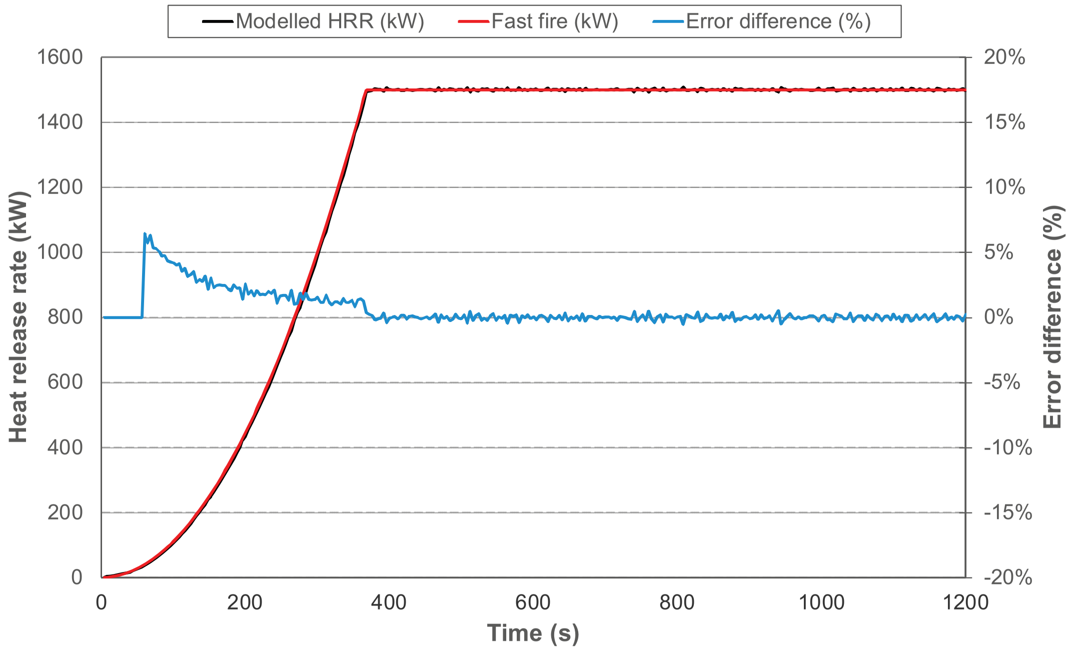
Timeline	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 200°C or greater, which corresponds to the limit for tenability for radiation.
20 minutes Temperatures are below 200°C with the exception of the area of the fire plume and ceiling jet.	

F.10.4 Temperature at 2m above floor level

Timeline	Lower ground floor	Ground floor (heritage void and south lobby)
	The colour blue indicates temperatures of approximately 20°C. The colour red indicates temperatures of 60°C or greater, which is the limit for tenability.	
20 minutes The temperature throughout the lower ground floor and the ground floor is less than 60°C with the exception of the area of fire origin.		

F.10.5 Error checking – heat release rate

The following graph compares the heat release rate specified in the FDS input file with the actual heat release rate measured in the output to confirm consistency. The graph shows consistency between input and output data with errors of less than 10% during the early growth phase when the fire size is small and less than 5% error once the peak fire size is reached.



Appendix G Evacuation modelling – alternative solution 1

G.1 Evacuation assessment framework

The IFEG states that the RSET is the time from when a fire initiates to the time when occupants reach a place of safety. The framework used to calculate the RSET is based upon Equation 6. The RSET is measured from the same point of origin as the fire at the time of initiation. The calculation of the RSET using Equation 6 is the addition of four periods, which are briefly described by the following:

- Cue period – the time of fire initiation to the time a cue indicates the occurrence of a fire.
- Response period – the time a cue indicates the occurrence of a fire to the time occupants recognise the cue as an indication of a fire.
- Delay period – the time occupants recognise the cue as an indication of fire to the time occupants commence evacuation.
- Movement period – the time occupants commence evacuation to the time when occupants reach a place of safety. This period is calculated on the basis of human walking speeds and queuing at exits affected by crowding.

RSET = cue period + response period + delay period + movement period

Equation 6 calculation of RSET

G.1.1 Evacuation scenarios

The evacuation scenarios described in Table 26 have been formulated based on the fire scenarios outlined in section 6.6 and the results of the smoke modelling presented in Appendix F.

Fire scenario	Area considered	Exit element	Exit availability	Cue type
Scenario 1 – heritage void	Lower ground floor	2m exit into bus bays 2m exit into loading dock	Available Available	Fire alarm + visual cue
	Ground floor (heritage void)	1.5m exit via bridge 1m exit south	Available Available	Fire alarm + visual cue
Scenarios 2, 3 and 5 – ground south	Ground floor (south)	4m main exits to Sussex St 1.6m exit via site link bridge 2m horizontal exit north	Available Available **Blocked**	Fire alarm + visual cue
	Southern mezzanine pre-function	2m horizontal exit south 2m horizontal exit north 3m main stair 1m exit via fire stair 2	Available Available Available **Blocked**	Fire alarm + visual cue
Scenario 4 – mezzanine south	Ground floor (south)	4m main exits to Sussex St 1.6m exit via site link bridge 2m horizontal exit north	Available Available **Blocked**	Fire alarm
	Southern mezzanine pre-function	2m horizontal exit south 2m horizontal exit north 3m main stair 1m exit via fire stair 2	Available Available **Blocked** **Blocked**	Fire alarm + visual cue
Scenario 6 – heritage void	Lower ground floor	2m exit into bus bays 2m exit into loading dock	Available Available	Fire alarm + visual cue
	Ground floor (heritage void)	1.5m exit via bridge 1m exit south	Available Available	Fire alarm + visual cue

Fire scenario	Area considered	Exit element	Exit availability	Cue type
	Ground floor (south)	4m main exits to Sussex St 1.6m exit via site link bridge 2m horizontal exit north	Available Available **Blocked**	Fire alarm

Table 29 Evacuation scenarios

G.1.2 Populations nominated

Table 30 summarises the populations relevant for each of the fire scenarios assessed. For fire scenarios on the ground floor, occupants in the southern pre-function area on the mezzanine are assumed to be obstructed from using the main, non-fire isolated stair and utilise the alternative horizontal exits leading to another fire compartment from where direct egress to outside is available.

The population numbers used in this assessment have been based upon advice from Bates Smart[76] and GL Investment Co[77].

Fire scenario	Area considered	Estimated population
Scenario 1 – heritage void	Lower ground floor	58
	Ground floor (heritage void)	54
Scenarios 2, 3 and 5 – ground south	Ground floor (south)	45 (lobby) + 104 (bar) + 20 (staff) + 178 (meeting rooms 1-3) = 347
	Ground floor (restaurant)	340
	Southern mezzanine pre-function	505
Scenario 4 – mezzanine south	Ground floor (south)	45 (lobby) + 104 (bar) + 20 (staff) + 178 (meeting rooms 1-3) + 340 (restaurant) = 347
	Southern mezzanine pre-function	505
Scenario 6 – heritage void – smoke curtain failure	Lower ground floor	58
	Ground floor (heritage void)	54
	Ground floor (south)	45 (lobby) + 104 (bar) + 20 (staff) + 178 (meeting rooms 1-3) + 340 (restaurant) = 347

Table 30 Populations used in evacuation calculations

Note: Scenario 6 was not specially modelled as the results can be determined from a combination of the results from modelling scenario 1 and scenario 4.

G.2 Cue period

The cue period is dependent on the fire location, the fire growth rate and the active detection systems provided within the area of fire origin. The cue time for this assessment is based upon the time for operation of smoke detectors and review of the smoke spread in the FDS models.

Smoke detectors spaced in accordance with AS 1670.1-2004 were located around the fires for each scenario – see appendix F.2 for detailed smoke detector properties. The detector activation times for the various scenarios are summarised in Table 31.

[76] Bates Smart markup. 161 Sussex Street – GF pax. 29 November 2013.
[77] GL Investment Co. Aconex GLIM-CA-000075 dated 13 December 2013.

Fire scenario	Detection method	FDS detector activation times (seconds)	Cue time assumed (seconds)
1. Medium t^2 fire – lower ground floor below heritage void	Smoke detection	50.1 48.3 47.5 48.3	60
2. Medium t^2 fire – ground floor bar	Smoke detection	46.3 45.4 44.7 45.3	60
3. Medium t^2 fire to 1.5MW – ground floor below southern void	Smoke detection	44.8 43.9 43.0 44.0	60
4. Medium t^2 fire – mezzanine floor southern pre-function	Smoke detection	45.5 44.3 43.8 44.2	60
5. Sensitivity - medium t^2 fire with second row sprinkler activation – ground floor bar	Smoke detection	46.3 45.4 44.7 45.3	60
6. Sensitivity - medium t^2 fire – lower ground floor below heritage void – smoke curtain failure	Smoke detection	50.1 48.3 47.5 48.3	60
Note – Results for multiple detectors have been included where applicable.			

Table 31 Cue period

G.3 Pre-movement phase

The period from when occupants receive a fire cue to the start of movement towards an exit is the total pre-movement time. The pre-movement phase comprises the response and the delay periods. The occupant response period involves the process of interpreting the automatic or intrinsic fire cue and identifying it as a cause for evacuation. Once occupants accept the need to respond to a fire cue, they may undertake activities such as investigating the fire, searching for family members, collecting belongings and first aid fire fighting prior to moving towards an exit. This is referred to as the delay period.

The pre-movement phase will vary between different occupants in the population. Occupants in the same room or area as the fire with visual access are likely to react faster than occupants in adjacent areas due to the increased sense of threat. The type of fire cue received will also influence the pre-movement time – ie smell of smoke, standard alert tones or verbal evacuation message.

The pre-movement phase for occupants within the zone of fire origin, who are assumed to receive visual and olfactory cues of a fire, is expected to range between almost no delay in the direct vicinity of the fire, up to 2 minutes further away from the fire – Figure 60[78] with an approximate design value of 1 minute. At this time significant smoke spread can be observed throughout the compartment of origin and those occupants closest to the fire can be expected to have commenced evacuation.

[78] Human Behaviour in Fire Emergencies, 2003, NFPA, USA.

A log-normal distributed pre-movement time with a minimum value of 0 seconds, a maximum value of 120 seconds, a mean of 60 seconds and a standard deviation of 30 seconds is used for the compartment of fire origin.

A pre-movement time of 3 minutes is assumed for adjacent smoke zones where occupants may not receive intrinsic cues[79, 80].

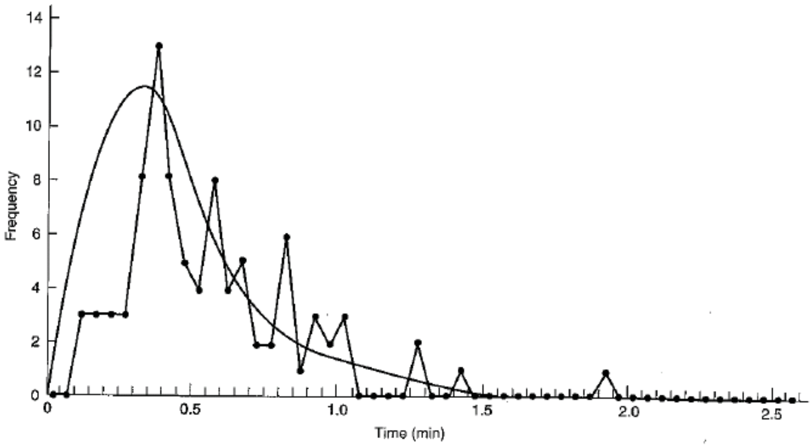


Figure 60 Experimental and theoretical pre-movement times in department stores

G.4 Movement phase

This section describes the evaluation of the times necessary for movement of occupants to the exits.

The movement time has been modelled using the software package Pathfinder[81]. Pathfinder is an agent based egress and human movement simulator. It provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis.

The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. Walls and other impassable areas are represented as gaps in the navigation mesh.

Doors are represented as special navigation mesh edges and provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow. Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway.

Occupants are modelled as upright cylinders on the movement mesh and travel using an agent based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters – maximum speed, exit choice, 3D model, etc. Occupants can be assigned to use specific exits based on the specific fire scenario being assessed.

Pathfinder supports two simulation modes. In steering mode, doors do not act to limit the flow of occupants, but occupants use the steering system to maintain a reasonable separation distance. In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density. SFPE mode was used for this assessment.

The SFPE mode implements the flow based egress modelling techniques presented in the SFPE Handbook of Fire Protection Engineering and the SFPE Engineering Guide: Human Behaviour in Fire. The SFPE calculation as described in the handbook is a flow model, where walking speeds and flow rates through doors, corridors and stairs are defined.

[79] The SFPE Hand of Fire Protection Engineering, 2002, 3rd edition, NFPA, USA, chapter 13, p 3-351.
[80] Fire engineering – CIBSE Guide E, 2010, 3rd edition, CIBSE Publications Department, pp 7-11.
[81] Pathfinder version 2012, by Thunderhead Engineering Consultants, http://www.thunderheadeng.com/pathfinder/index.html

G.5 Movement modelling – scenario 1

G.5.1 Model geometry and occupant distribution

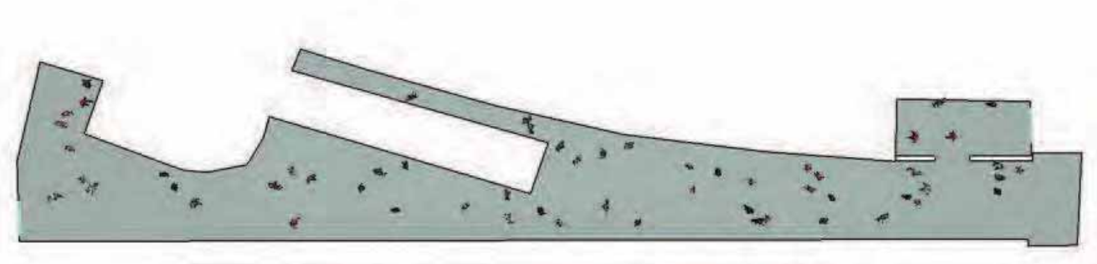


Figure 61 Model geometry showing starting location of occupants within heritage void – lower ground level

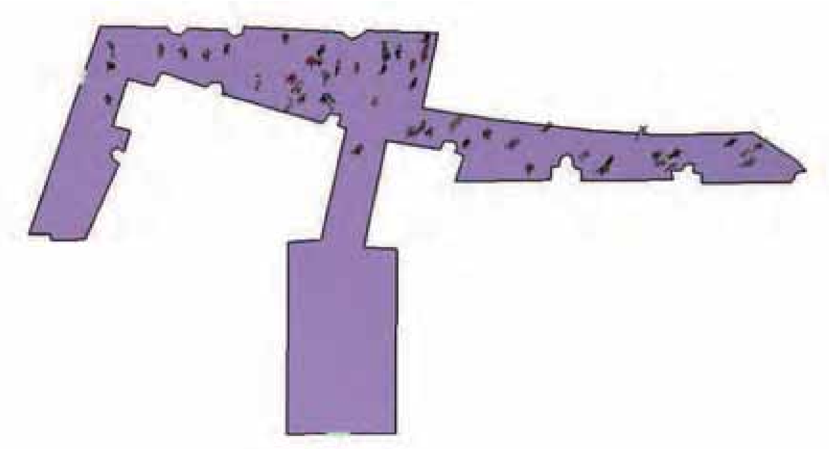
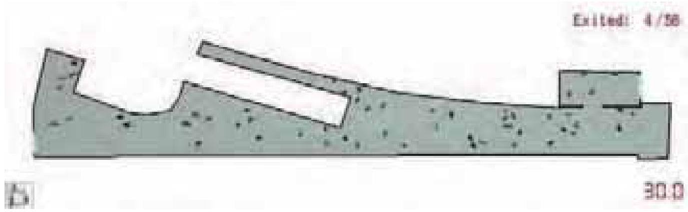
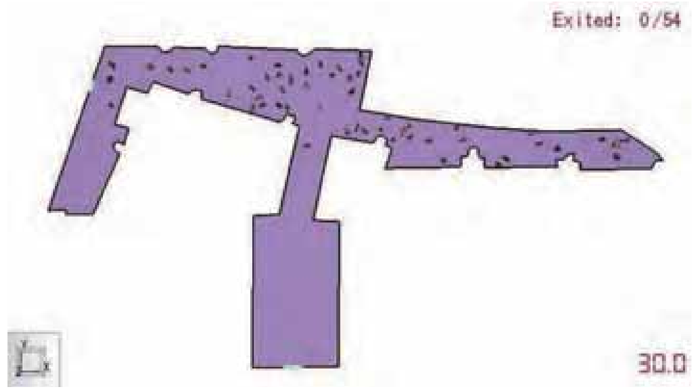
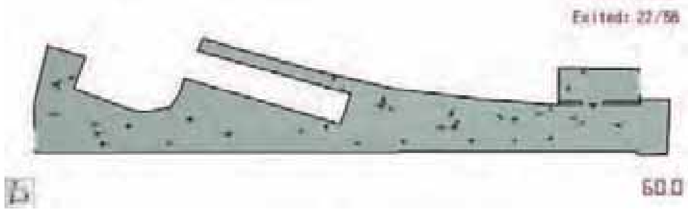
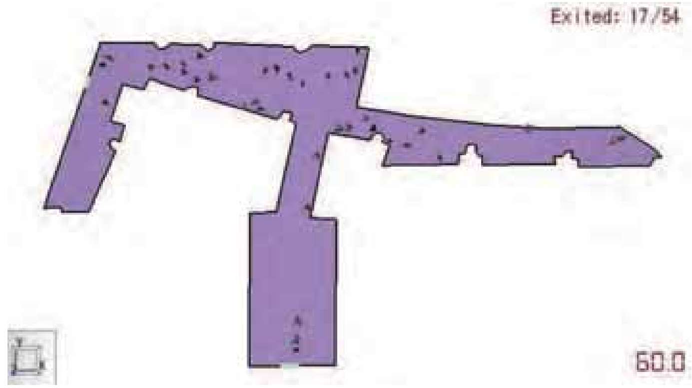
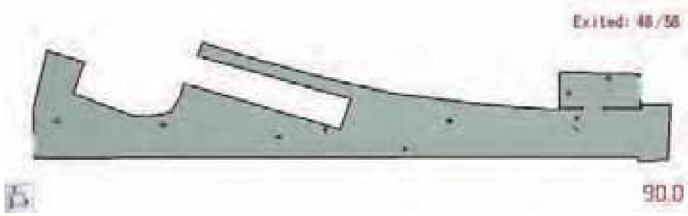
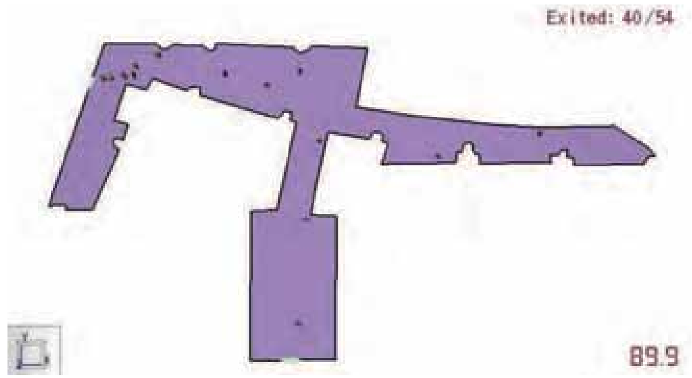
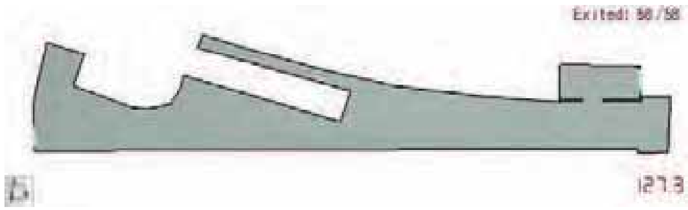
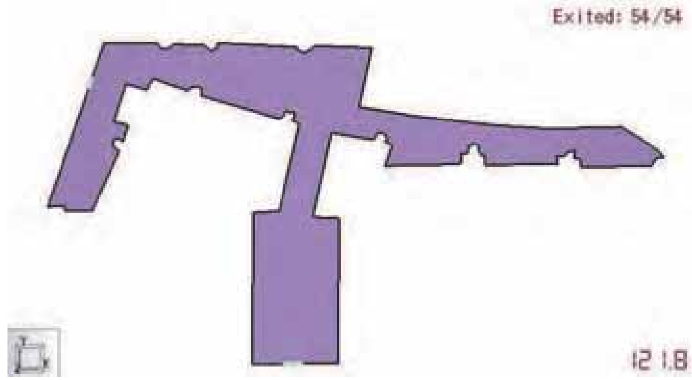


Figure 62 Model geometry showing starting location of occupants within heritage void – ground level

G.5.2 Modelling results

Timeline	Lower ground floor	Ground floor (heritage void)
30 seconds (0.5 minutes) Both floors begin evacuation at the same time. Only a few occupants have begun evacuating on the lower ground floor.		
60 seconds (1 minute) More occupants on both floors begin to evacuate towards their nearest exit		

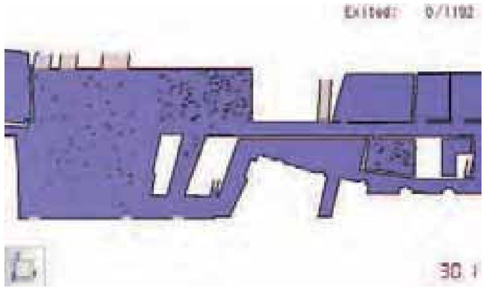
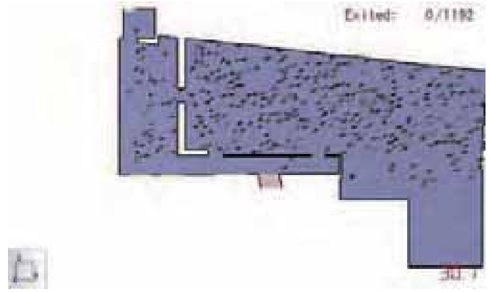
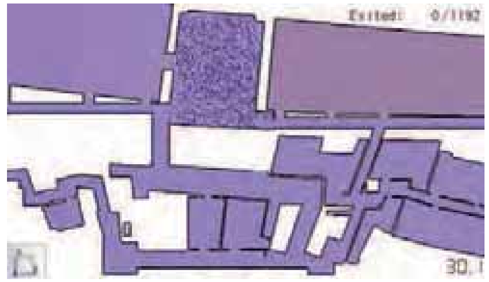
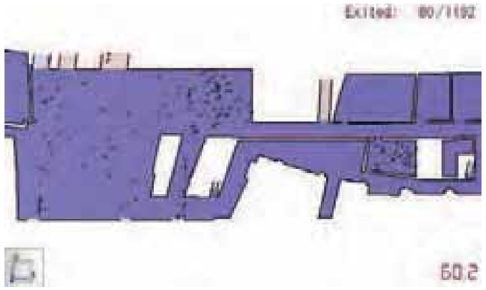
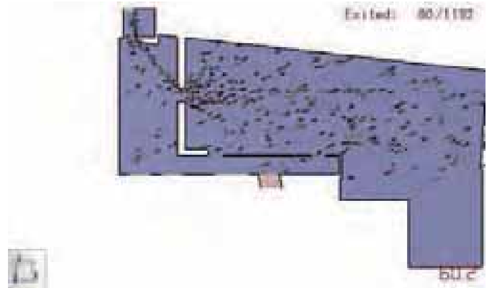
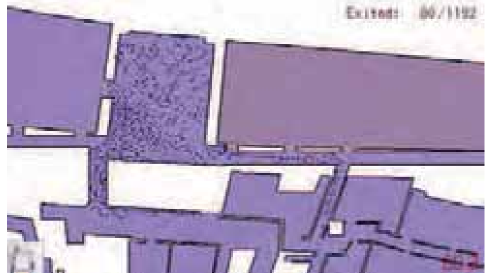
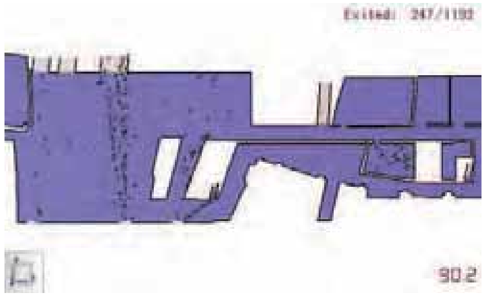
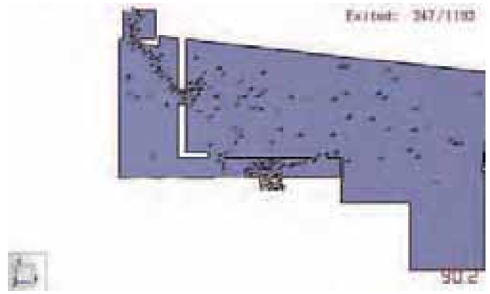
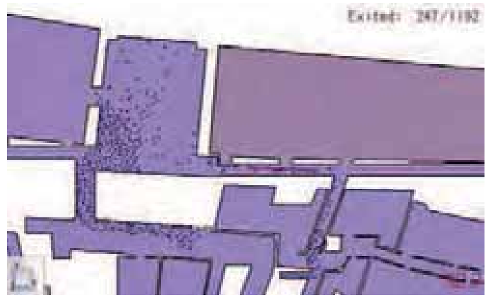
Timeline	Lower ground floor	Ground floor (heritage void)
90 seconds (1.5 minutes) Majority of occupants have evacuated the lower ground floor. More than half the occupants have evacuated from the ground floor heritage void.		
127/122 seconds (2.1/2 minutes) Both levels have completed evacuation.		

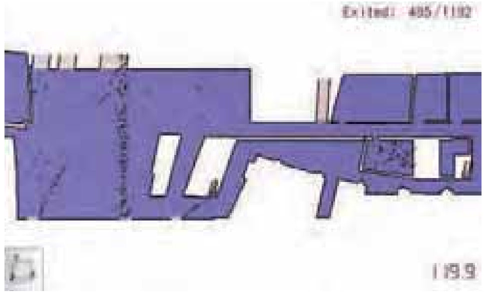
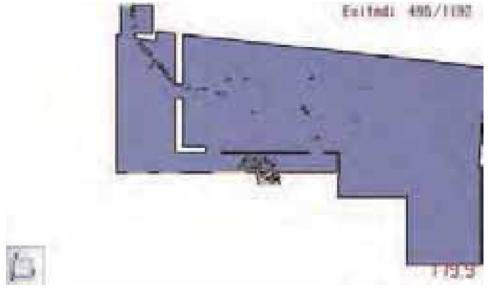
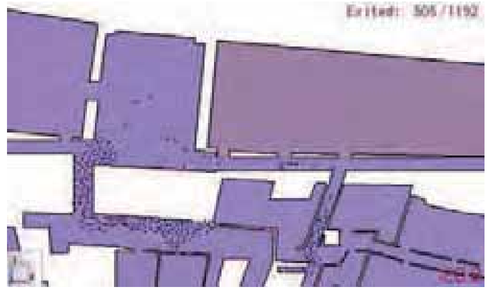
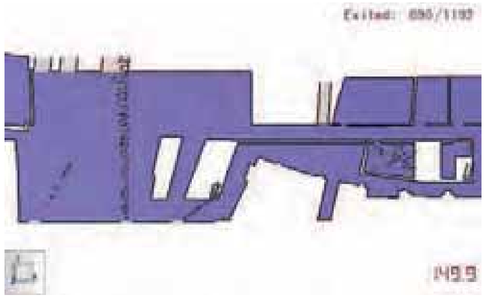
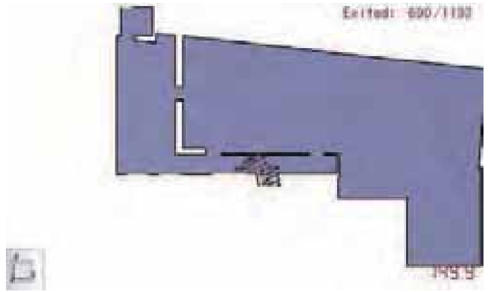
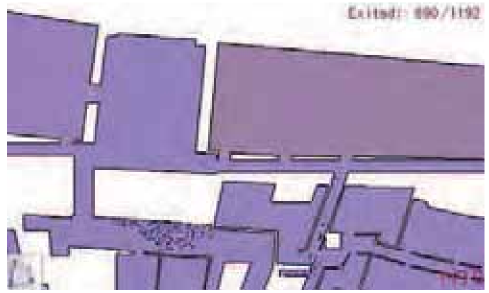
G.6 Movement modelling – scenarios 2, 3 and 5

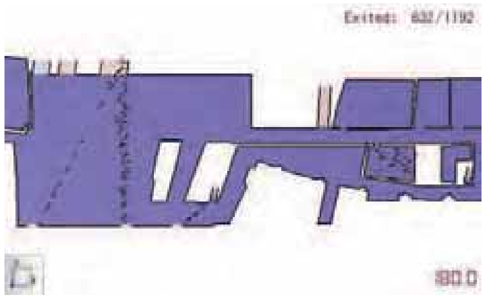
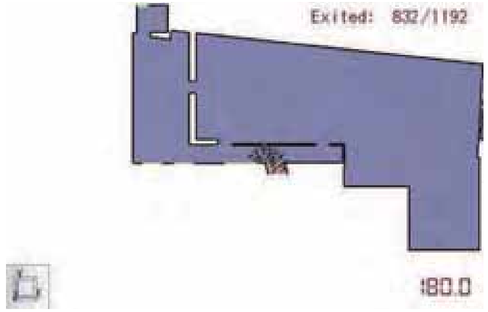
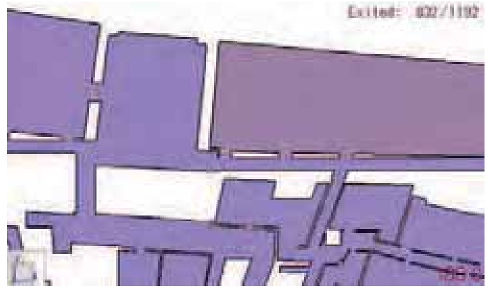
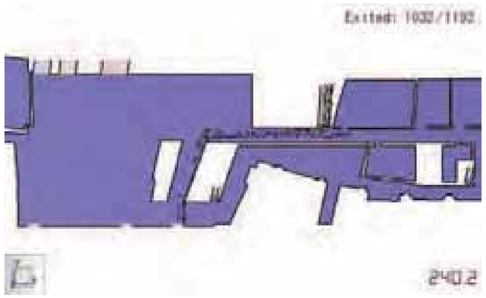
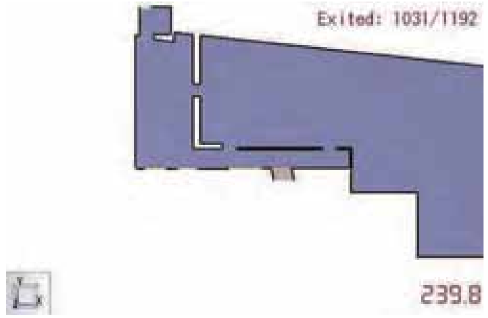
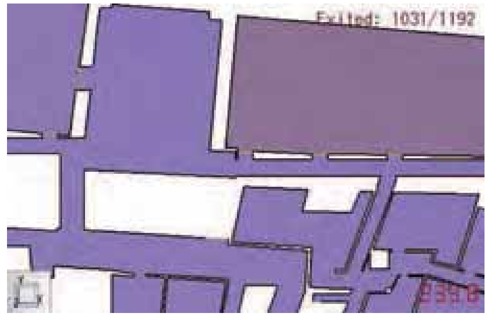
G.6.1 Model geometry and occupant distribution

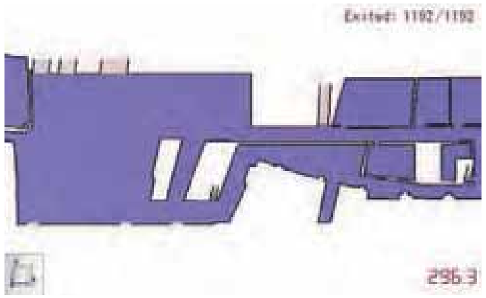
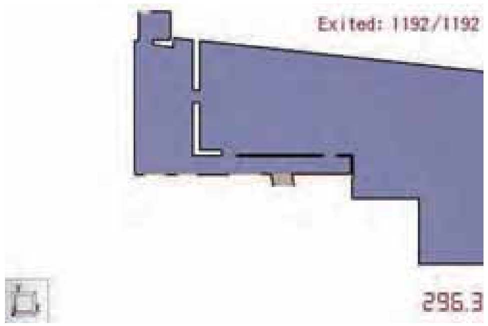
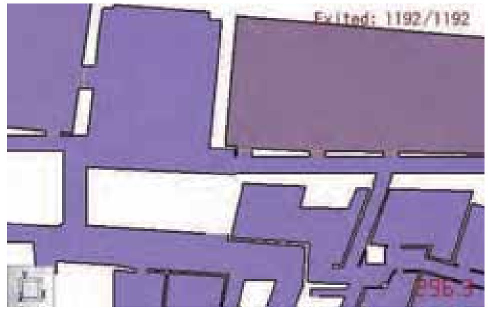
Figure 63 Model geometry showing starting location of occupants within the southern ground and mezzanine floors

G.6.2 Modelling results

Timeline	Ground floor	Ground floor restaurant	Mezzanine southern pre-function
30 seconds **(0.5 minutes)** Both floors begin evacuation at the same time. Only a few occupants have begun evacuating on both floors.			
60 seconds **(1 minute)** More occupants on both floors begin to evacuate towards their nearest exit			
90 seconds **(1.5 minutes)** Occupants continue to evacuate on both floors. Occupants begin queuing at the main feature stair on the mezzanine floor.			

Timeline	Ground floor	Ground floor restaurant	Mezzanine southern pre-function
120 seconds **(2 minutes)** The majority of occupants have evacuated the restaurant. Occupants continue to cue at the main feature stair on the mezzanine floor			
150 seconds **(2.5 minutes)** The restaurant has completed evacuation. The majority of occupants have evacuated the mezzanine southern pre-function.			

Timeline	Ground floor	Ground floor restaurant	Mezzanine southern pre-function
180 seconds **(3 minutes)** The southern pre-function on the mezzanine floor has completed evacuation. Occupants continue down the main feature stair and proceed to the main exits on the ground floor.			
240 seconds **(4 minutes)** Occupants have begun evacuating from the adjoining fire compartments.			

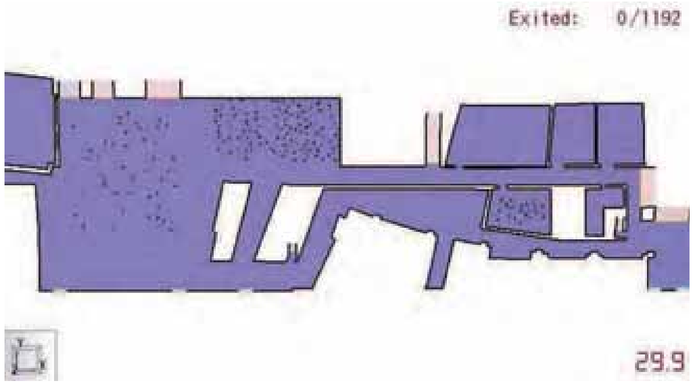
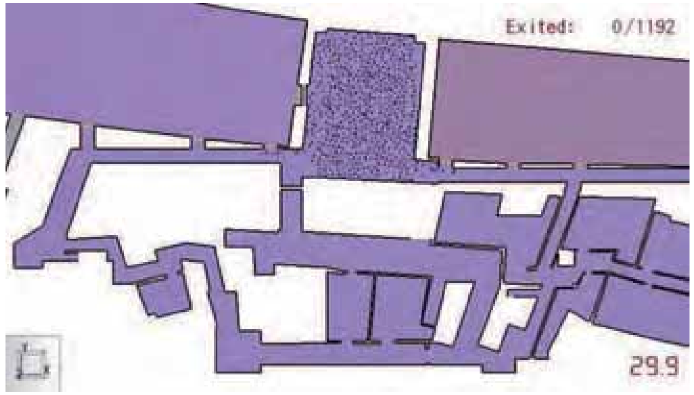
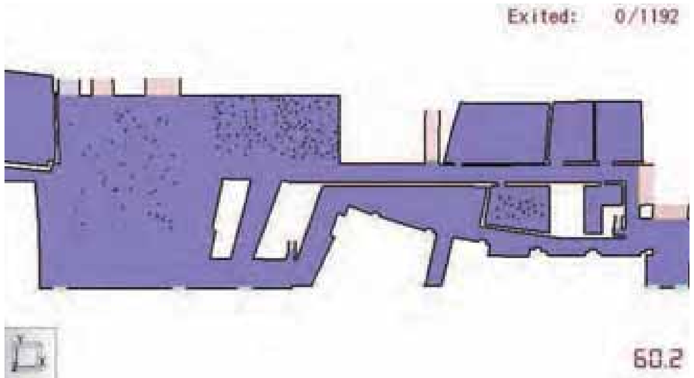
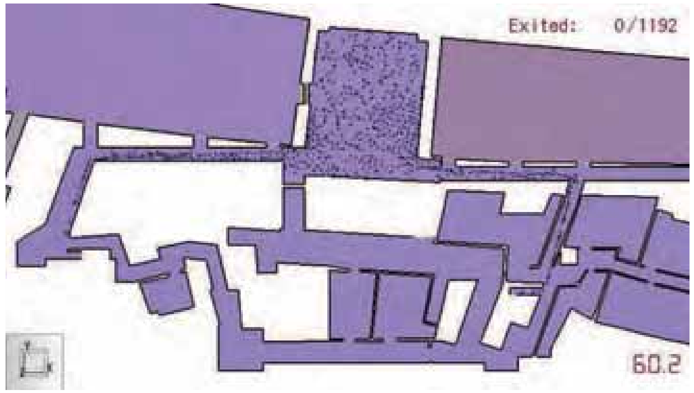
Timeline	Ground floor	Ground floor restaurant	Mezzanine southern pre-function
300 seconds **(5 minutes)** Both levels have completed evacuation.			

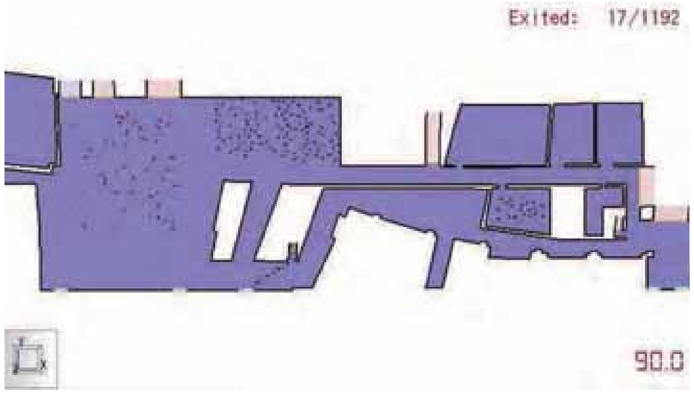
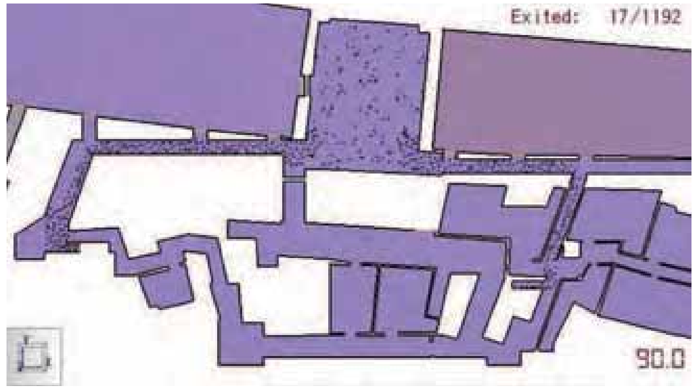
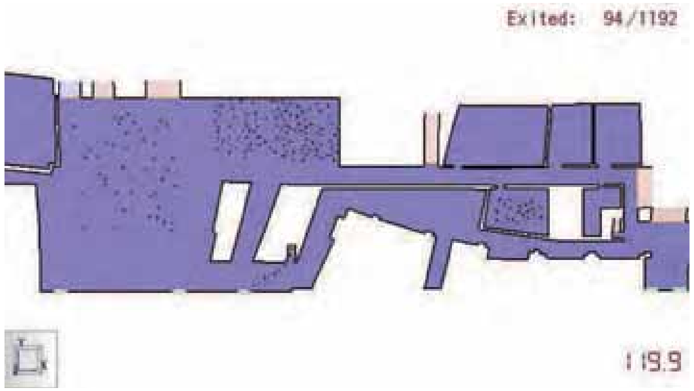
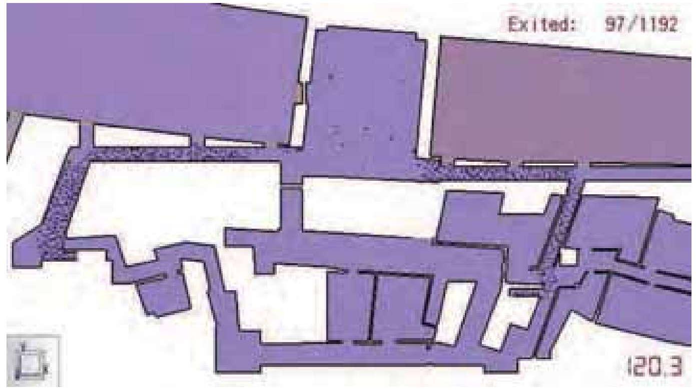
G.7 Movement modelling – scenario 4

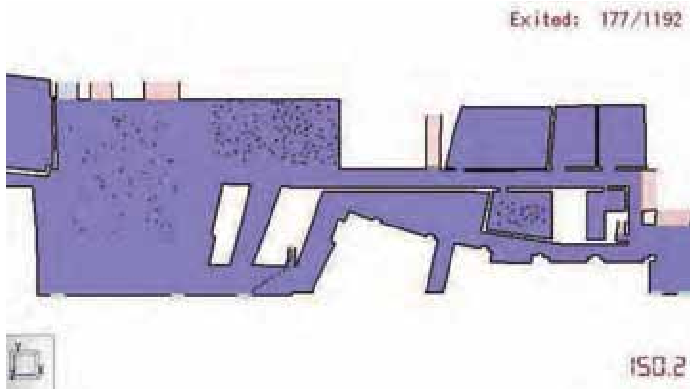
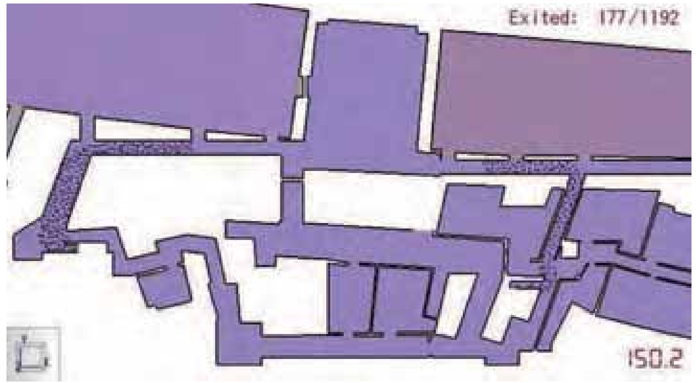
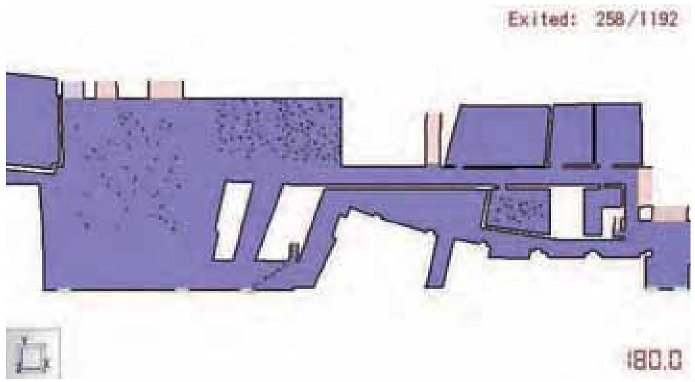
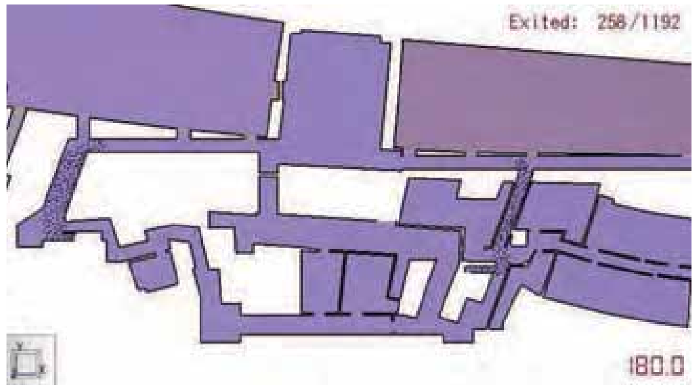
G.7.1 Model geometry and occupant distribution

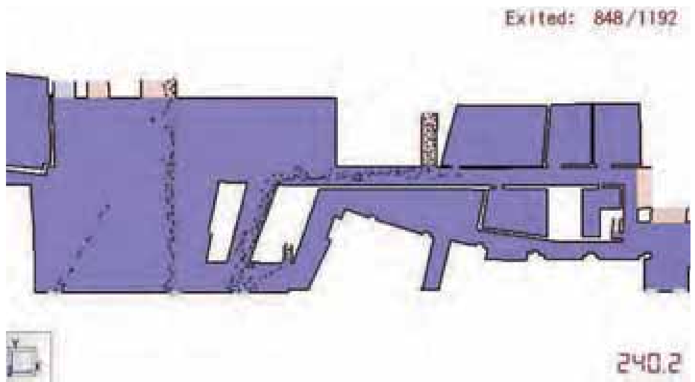
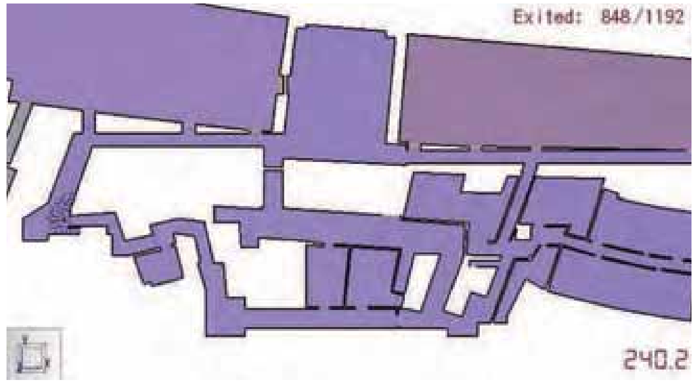
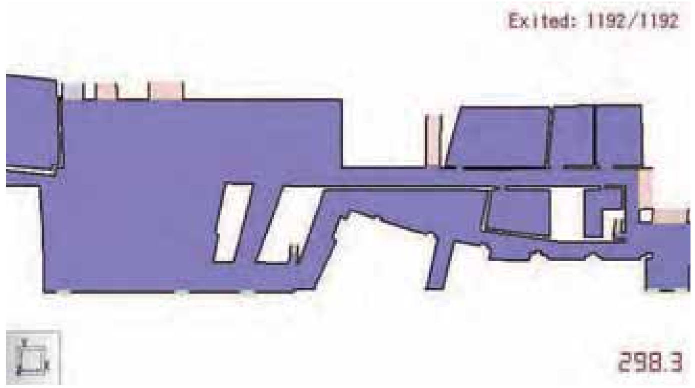
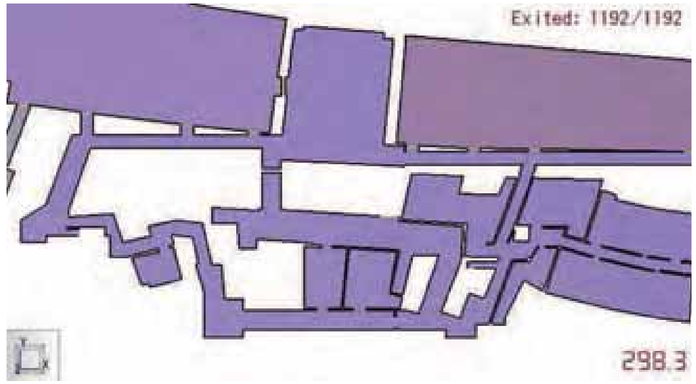
Figure 64 Model geometry showing starting location of occupants within the southern ground and mezzanine floors

G.7.2 Modelling results

Timeline	Ground floor	Mezzanine floor
30 seconds (0.5 minutes) Only a few occupants have begun evacuating on the mezzanine floor. Occupants on the ground floor have not begun evacuation as they may not be aware of a fire on the floor above.		
60 seconds (1 minute) More occupants on the mezzanine floor begin to evacuate towards their nearest exit to the adjoining fire compartments to the north and south. The main feature stair is blocked. Occupants on the ground floor have not begun evacuation as they may not be aware of a fire on the floor above.		

Timeline	Ground floor	Mezzanine floor
90 seconds (1.5 minutes) Occupants on the mezzanine floor continue to evacuate to the adjacent fire compartment. Occupants on the ground floor have not begun evacuation as they may not be aware of a fire on the floor above.		
120 seconds (2 minutes) The majority of occupants have evacuated the southern pre-function space on the mezzanine floor to the adjacent fire compartments. Occupants on the ground floor have not begun evacuation as they may not be aware of a fire on the floor above.		

Timeline	Ground floor	Mezzanine floor
150 seconds (2.5 minutes) The southern pre-function mezzanine occupants have completed evacuation to a place of safety in the adjacent fire compartments. Occupants on the ground floor have not begun evacuation as they may not be aware of a fire on the floor above.		
180 seconds (3 minutes) Occupants on the ground floor begin to evacuate to their nearest exit.		

Timeline	Ground floor	Mezzanine floor
240 seconds (4 minutes) Occupants on the ground continue to evacuate to their nearest exit.		
300 seconds (5 minutes) Both levels have completed evacuation.		

G.8 RSET summary

The total RSETs for the various evacuation scenarios assessed are summarised in Table 32.

Fire scenario	Area considered	Cue type	Cue period (minutes)	Movement period – including distributed pre-movement (minutes)	RSET (minutes)
Scenario 1 – heritage void	Lower ground floor	Alarm + intrinsic	1	2.1	**3.1**
	Ground floor (heritage void)	Alarm + intrinsic	1	2	**3**
Scenarios 2, 3 and 5 – ground south	Ground floor (south)	Alarm + intrinsic	1	5	**6**
	Ground floor (restaurant)	Alarm + intrinsic	1	2.5	**3.5**
	Southern mezzanine pre-function	Alarm + intrinsic	1	3	**4**
Scenario 4 – mezzanine south	Ground floor (south)	Alarm	1	5	**6**
	Southern mezzanine pre-function	Alarm + intrinsic	1	2.5	**3.5**
Scenario 6 – heritage void – smoke curtain failure	Lower ground floor	Alarm + intrinsic	1	2.1	**3.1**
	Ground floor (heritage void)	Alarm + intrinsic	1	2	**3**
	Ground floor (south)	Alarm	1	5	**6**

Table 32 RSET summary

Appendix H Evacuation modelling – alternative solution 2

H.1 Evacuation assessment framework

The IFEG states that the RSET is the time from when a fire initiates to the time when occupants reach a place of safety. The framework used to calculate the RSET is based upon Equation 7. The RSET is measured from the same point of origin as the fire at the time of initiation. The calculation of the RSET using Equation 7 is the addition of four periods, which are briefly described by the following:

- Cue period – the time of fire initiation to the time a cue indicates the occurrence of a fire.
- Response period – the time a cue indicates the occurrence of a fire to the time occupants recognise the cue as an indication of a fire.
- Delay period – the time occupants recognise the cue as an indication of fire to the time occupants commence evacuation.
- Movement period – the time occupants commence evacuation to the time when occupants reach a place of safety. This period is calculated on the basis of human walking speeds and queuing at exits affected by crowding.

RSET = cue period + response period + delay period + movement period

Equation 7 calculation of RSET

H.1.1 Evacuation scenarios

The evacuation scenarios described in Table 29 have been formulated based on the fire scenarios outlined in section 7.7. The available exits is the same in both the proposed design and the base case. For conservatism, the 2m wide southern horizontal exit to fire compartment 1 in the proposed design has been assumed to be blocked.

Fire scenario	Area considered	Exit element	Exit availability	Cue type
Fire in the northern ground floor lobby	Northern ground floor	2m exit into northern courtyard 2m exit into northern courtyard 1m exit into northern courtyard	Available Available Available	Fire alarm + visual cue

Table 33 Evacuation scenarios

H.1.2 Populations nominated

Table 27 summarises the population relevant for the fire scenario being assessed – being a fire within the northern lobby on the ground floor in fire compartment 2. The populations in the base case and the proposed design are assumed to be equivalent for the purposes of the assessment.

The population numbers used in this assessment have been based upon advice from Bates Smart[82] and GL Investment Co[83]. The maximum population of meeting rooms 1-5 – in the adjoining fire compartment 5 – have been included in the assessment to account for the worst case scenario where they may be waiting within the northern lobby.

Area	Estimated population
Meeting rooms 1-5	356 patrons
Meeting rooms 6-11	102 patrons
6% Staff	28 staff
Total	**486 persons**

Table 34 Population estimate

[82] Bates Smart markup. 161 Sussex Street – GF pax. 29 November 2013.
[83] GL Investment Co. Aconex GLIM-CA-000075 dated 13 December 2013.

H.2 Cue period

The cue periods for the proposed design and the base case are based upon the time of activation of the smoke detection system, calculated using FDS modelling. The times of activation were calculated using a floor-to-ceiling height of 2.9m. Although it is recognised that parts of the floor have a floor-to-ceiling height of 3.5m, it is noted that a lower ceiling height results in more conservative results when undertaking the comparative assessment.

The predicted cue periods are summarised within Table 35 and included in Appendix J.

H.2.1 Design scenario – medium t^2 fire growth rate

Building	Detection method	Cue time (seconds)
Proposed design	AS 1670.1 smoke detection	48
Base case	AS/NZS 1668.1 smoke detection	92

Table 35 Cue period

H.3 Pre-movement phase

The period from when occupants receive a fire cue to the start of movement towards an exit is the total pre-movement time. The pre-movement phase comprises the response (P_r) and the delay (P_d) periods. The occupant response period involves the process of interpreting the automatic or intrinsic fire cue and identifying it as a cause for evacuation. Once occupants accept the need to respond to a fire cue, they may undertake activities such as investigating the fire, searching for family members, collecting belongings and first aid fire fighting prior to moving towards an exit. This is referred to as the delay period.

The pre-movement phase will vary between different occupants in the population. The type of fire cue received will also influence the pre-movement time – ie smell of smoke, standard alert tones or verbal evacuation message.

Smoke detectors are present within the proposed design and the base case and the population in both cases are considered the same as discussed in Appendix H.1.2. The pre-movement phase for the base case and proposed design are therefore considered equivalent.

H.4 Movement phase

H.4.1 Basis for calculations

This section describes the evaluation of the time necessary for occupants to reach exits and pass through the exits to a place of safety. The movement time is a function of the population, the occupant density, the movement speed and flow rate through paths of travel and exits. The methodology for calculating the evacuation time is based on the information provided in the SFPE Handbook.

Pathfinder modelling is not proposed to be used for this assessment as it is not considered an appropriate tool to compare the proposed design and the base case with respect to extended travel distances. The extended travel distances are directly related to the floor layout.

In order for a comparable base case to be constructed within Pathfinder, the layout of the proposed floor would need to be modified to reduce travel distances to a point of choice from 30m to 20m and from the nearest exit from 50m to 40m. In modifying the floor layout, the proposed design and the base case cannot be considered a direct comparison.

Therefore, the SFPE hand calculation methodology is considered more appropriate for the comparative assessment.

It is recognised that there has been recent debate about the validity of data and recommendations previously relied upon for egress design[84]. This is due to 'demographic changes, especially reduced fitness levels brought on by increasing sedentary lifestyles, increased body size and increased body weight' and 'reduced individual and societal motivation plus physiological condition.' In the absence of updated research data, it is considered that the previously adopted data is still applicable, particularly given the level of conservatism inbuilt into the other aspects of the quantitative assessment and the comparison the a DTS-complying base case which adopts the same methodology.

H.4.2 Travel to exits

Observations and experiments have shown that evacuation flow speed of a group is a function of the population density. On the flat where the occupant density exceeds 0.5 persons/m^2, the SFPE Handbook[85] and CIBSE Guide E[86] specify walking speeds of approximately 1.2m/s. A walking speed of 1.0m/s is conservatively adopted for this assessment to account for variations in occupant characteristics.

Exit travel distances are based on the following:

1. Travel distance to a point of choice:
   - Base case – 20m
   - Proposed design – 30m
2. Travel distance to the nearest exit
   - Base case – 40m
   - Proposed design – 50m

H.4.3 Flow through exits

The flow rate through paths of travel and exits is a function of clear width and the exit route element – ie doorway, corridor, stair etc. The useful or effective width of an exit is the clear width of the exit less the boundary layers. Table 36 outlines the boundary layers and exit flow rates used in the assessment to determine the queuing time at exits[87].

Exit route element	Boundary layer (m)	Exit flow rate Persons/min/m	Exit flow rate Persons/s/m
Doorways – with self closing doors that need to be held open*	NA	Single leaf door = 50 Double leaf door = 100	Single leaf door = 0.83 Double leaf door = 1.66
Doorways – unobstructed**	0.15	78	1.3
Corridor, ramp	0.2	78	1.3
Stairs – wall or side of tread	0.15	60	1.01
Stairs – handrail	0.09	60	1.01

Notes:
* Fixed flow rate irrespective of door width.
** A minimum flow rate of 50persons/min is assumed for single doors.

Table 36 Boundary layers and flow rates for exit elements

H.4.4 Calculation of travel time

The evacuation calculations are included in Table 37 and Table 38.

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84 JL Pauls, 2008, Performance of means of egress – Conducting the research needed to establish realistic expectations, in Proceedings, 7th International Conference on Performance-Based Codes and Fire Safety Design Methods.
85 The SFPE Handbook of Fire Protection Engineering. 2008, 4th edition, NFPA, USA, chapter 13, pp 3-378 and 3-381.
86 Fire engineering – CIBSE Guide E, 3rd edition, 2010, CIBSE Publications Department, pp 7-11.
87 The SFPE Handbook of Fire Protection Engineering. 2008, 4th edition, NFPA, USA, chapter 13, pp 3-378 and 3-381.

Effective flow rates of elements		
Exit element	**Effective width (m)**	**Effective flow rate (persons/min)**
Northern courtyard exit 1 Doorway (unobstructed)	1.70	133
Northern courtyard exit 2 Doorway (unobstructed)	1.70	133
Northern courtyard exit 3 Doorway (unobstructed)	0.70	55
Queuing calculation		
Population	486	
Total effective flow rate (persons/min)	320	From SFPE Handbook
Queuing time (s)	**92**	= 1.6 mins
Travel time calculation		
Travel distance (m)	50	
Travel speed (m/s)	1	From SFPE Handbook
Travel time (s)	**50**	= 0.9 mins
Summary		
Total evacuation time (s)	**92**	= 1.6 mins
Note: Queuing time exceeds travel time		

Table 37 Occupant evacuation time calculations for the proposed design – travel to the nearest exit

Effective flow rates of elements		
Exit element	**Effective width (m)**	**Effective flow rate (persons/min)**
Northern courtyard exit 1 Doorway (unobstructed)	1.70	133
Northern courtyard exit 2 Doorway (unobstructed)	1.70	133
Northern courtyard exit 3 Doorway (unobstructed)	0.70	55
Queuing calculation		
Population	486	
Total effective flow rate (persons/min)	320	From SFPE Handbook
Queuing time (s)	**92**	= 1.6 mins
Travel time calculation		
Travel distance (m)	40	
Travel speed (m/s)	1	From SFPE Handbook
Travel time (s)	**40**	= 0.7 mins
Summary		
Total evacuation time (s)	**92**	= 1.6 mins
Note: Queuing time exceeds travel time		

Table 38 Occupant evacuation time calculations for the base case – travel to the nearest exit

H.5 RSET summary

The calculated RSETs for the proposed design and the base case are summarised in Table 39.

Building	Measure	Cue period	Pre-movement phase	Movement period	RSET excl. pre-movement phase
Proposed design	Point of choice	48s	Equivalent	30s	**78s**
	Nearest exit	48s	Equivalent	92s	**140s**
DTS compliant base case	Point of choice	92s	Equivalent	20s	**112s (> 78s)**
	Nearest exit	92s	Equivalent	92s	**184s (> 140s)**

Table 39 Comparison of RSETs – based on smoke detection system cue

Appendix I Evacuation modelling – alternative solution 3

I.1 Evacuation assessment framework

The IFEG states that the RSET is the time from when a fire initiates to the time when occupants reach a place of safety. The framework used to calculate the RSET is based upon Equation 8. The RSET is measured from the same point of origin as the fire at the time of initiation. The calculation of the RSET using Equation 8 is the addition of four periods, which are briefly described by the following:

- Cue period – the time of fire initiation to the time a cue indicates the occurrence of a fire.
- Response period – the time a cue indicates the occurrence of a fire to the time occupants recognise the cue as an indication of a fire.
- Delay period – the time occupants recognise the cue as an indication of fire to the time occupants commence evacuation.
- Movement period – the time occupants commence evacuation to the time when occupants reach a place of safety. This period is calculated on the basis of human walking speeds and queuing at exits affected by crowding.

RSET = cue period + response period + delay period + movement period

Equation 8 calculation of RSET

I.1.1 Evacuation scenarios

The evacuation scenarios described in Table 40 have been formulated based on the fire scenarios outlined in section 8.7. The available exits is the same in both the proposed design and the base case, however the proposed design has additional horizontal exits.

Fire scenario	Additional exit element in proposed design	Exit availability
1. Fire in southern pre-function room (fire compartment 1)	2m horizontal exit fire compartment 1 to 3 2m horizontal exit fire compartment 1 to 4	Available Available
2. Fire in northern pre-function room (fire compartment 2)	2m horizontal exit fire compartment 2 to 4	**Blocked**
3. Fire in southern function room (fire compartment 3)	2m horizontal exit fire compartment 3 to 1 2m horizontal exit fire compartment 3 to 1 2m horizontal exit fire compartment 3 to 1 2m horizontal exit fire compartment 3 to 1 2m horizontal exit fire compartment 1 to 4	Available Available Available Available Available
4. Fire in northern function room (fire compartment 4)	2m horizontal exit fire compartment 4 to 1 2m horizontal exit fire compartment 4 to 1 2m horizontal exit fire compartment 4 to 1 2m horizontal exit fire compartment 4 to 1 2m horizontal exit fire compartment 4 to 2 2m horizontal exit fire compartment 4 to 2 1m horizontal exit fire compartment 4 to 2 1m horizontal exit fire compartment 4 to 2	Available Available Available Available Available Available Available Available Available

Table 40 Evacuation scenarios

I.1.2 Populations nominated

Table 41 summarises the population relevant for the fire scenario being assessed.

The population numbers used in this assessment have been based upon advice from Bates Smart[88] and GL Investment Co[89].Given the various modes of operation of the function rooms, the maximum population of the fire compartment being assessed have been used in the assessment to account for the worst case scenario.

<table>
<tr><th>Area</th><th>Base case</th><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 3</th><th>Scenario 4</th></tr>
<tr><td>Ground floor total</td><td>1011</td><td>1011</td><td>1011</td><td>1011</td><td>1011</td></tr>
<tr><td>Mezzanine southern function</td><td>600</td><td>1100</td><td>700</td><td>1100</td><td>100</td></tr>
<tr><td>Mezzanine northern function</td><td>600</td><td>100</td><td>696</td><td>100</td><td>1000</td></tr>
<tr><td>Mezzanine southern pre-function</td><td rowspan="3">100</td><td>500</td><td>50</td><td>500</td><td>500</td></tr>
<tr><td>Mezzanine northern pre-function</td><td rowspan="2">100</td><td>504</td><td rowspan="2">100</td><td rowspan="2">200</td></tr>
<tr><td>Other areas</td><td>50</td></tr>
<tr><td>Mezzanine total</td><td>1300</td><td>1800</td><td>1800</td><td>1800</td><td>1800</td></tr>
</table>

Table 41 Population estimate

I.2 Cue period

The cue periods for the proposed design and the base case are based upon the time of activation of the smoke detection system, calculated using FDS modelling. The times of activation were calculated using a floor-to-ceiling height of 2.9m. Although it is recognised that parts of the floor have a floor-to-ceiling height of greater than 6m, it is noted that a lower ceiling height results in more conservative results when undertaking the comparative assessment.

The predicted cue periods are summarised within Table 42 and included in Appendix J.

I.2.1 Design scenario – medium t^2 fire growth rate

Building	Detection method	Cue time (seconds)
Proposed design	AS 1670.1 smoke detection	48
Base case	AS/NZS 1668.1 smoke detection	92

Table 42 Cue period

[88] Bates Smart markup. 161 Sussex Street – GF pax. 29 November 2013.
[89] GL Investment Co. Aconex GLIM-CA-000075 dated 13 December 2013.

I.3 Pre-movement phase

The period from when occupants receive a fire cue to the start of movement towards an exit is the total pre-movement time. The pre-movement phase comprises the response (P_r) and the delay (P_d) periods. The occupant response period involves the process of interpreting the automatic or intrinsic fire cue and identifying it as a cause for evacuation. Once occupants accept the need to respond to a fire cue, they may undertake activities such as investigating the fire, searching for family members, collecting belongings and first aid fire fighting prior to moving towards an exit. This is referred to as the delay period.

The pre-movement phase will vary between different occupants in the population. The type of fire cue received will also influence the pre-movement time – ie smell of smoke, standard alert tones or verbal evacuation message.

Smoke detectors are present within the proposed design and the base case and the type of occupants in both cases are considered the same. The pre-movement phase for the base case and proposed design are therefore considered equivalent.

I.4 Movement phase

The movement time has been modelled using the software package Pathfinder. Information on Pathfinder has previously been provided in Appendix G.4.

I.5 Movement modelling – base case

I.5.1 Model geometry and occupant distribution

Figure 65 Model geometry showing starting location of occupants

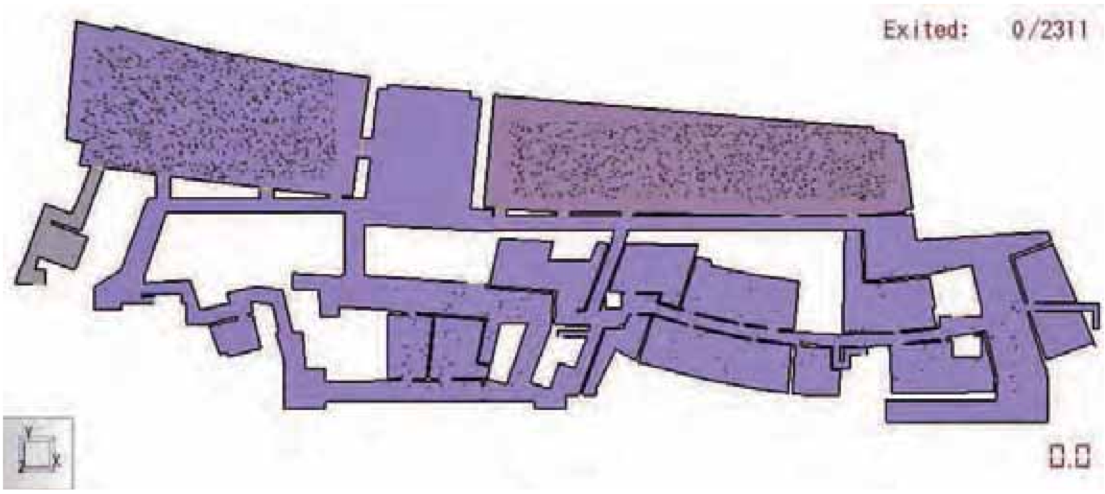
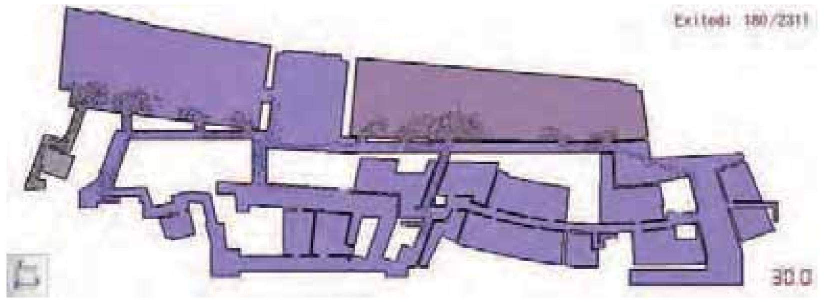
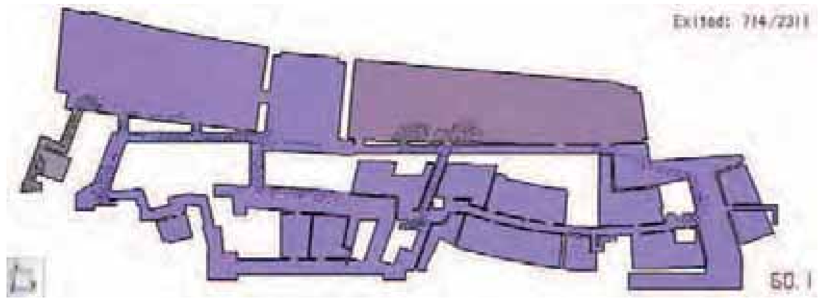
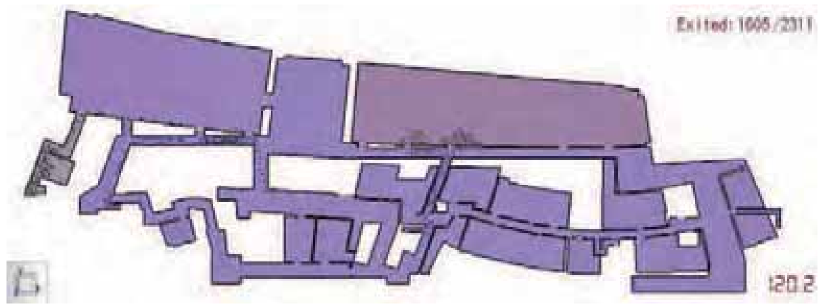
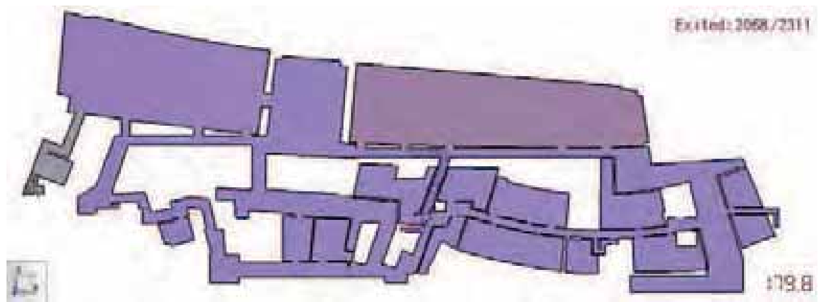
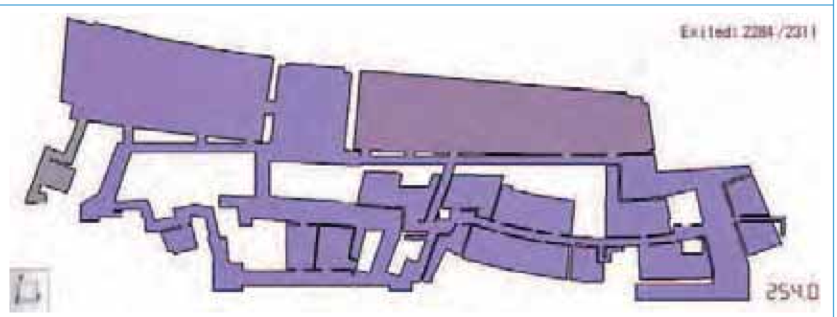


Figure 66 Model geometry showing starting location of occupants on the mezzanine floor

I.5.2 Modelling results

Timeline	Mezzanine floor
30 seconds (0.5 minutes) Occupants begin to evacuate towards their nearest exit.	
60 seconds (1 minute) Occupants begin queuing at exits.	
120 seconds (2 minutes) Occupants continue to queue at the exits. The majority of occupants have evacuated the mezzanine floor.	
180 seconds (3 minutes) Occupants continue to queue at fire stair 56. The remainder of the mezzanine floor is evacuated.	
254 seconds (4.2 minutes) Occupants from the mezzanine level are considered to have reached a place of safety.	

I.6 Movement modelling – scenario 1 – southern pre-function

I.6.1 Model geometry and occupant distribution

Figure 67 Model geometry showing starting location of occupants

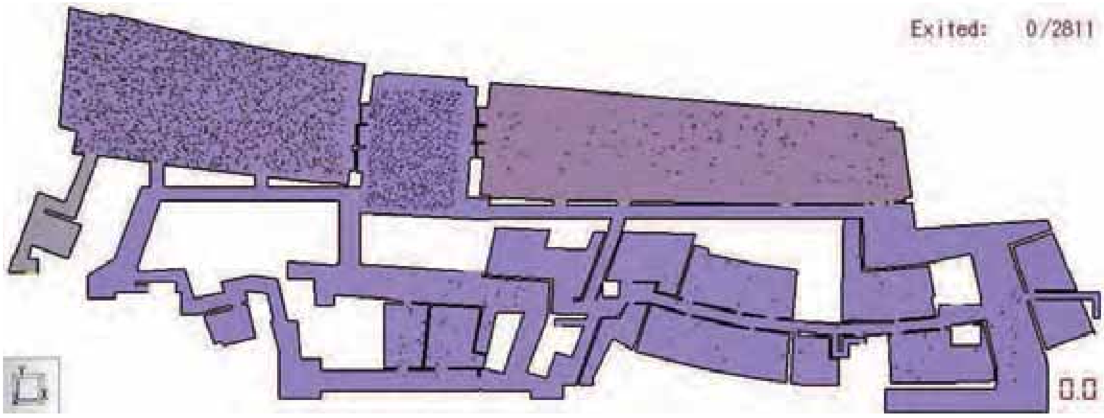
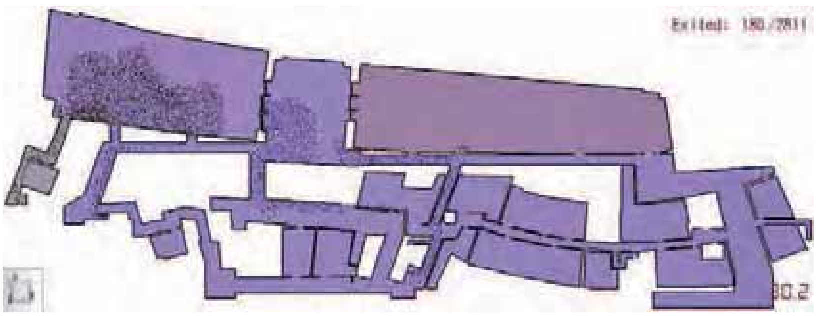
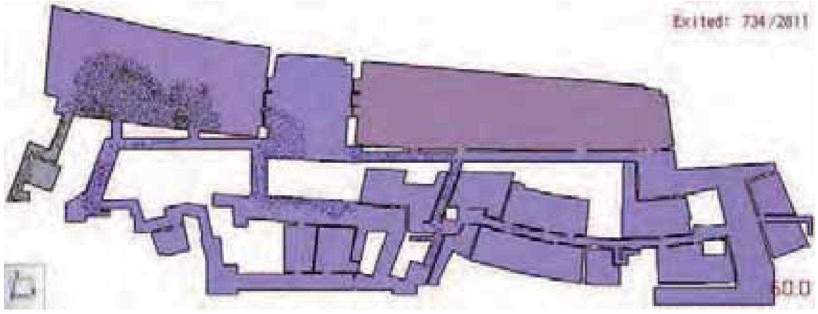
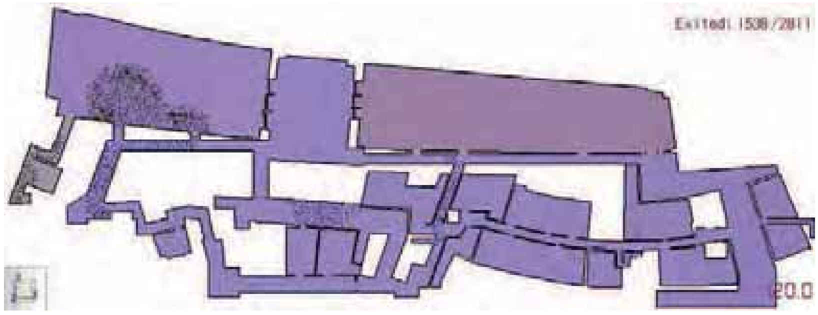
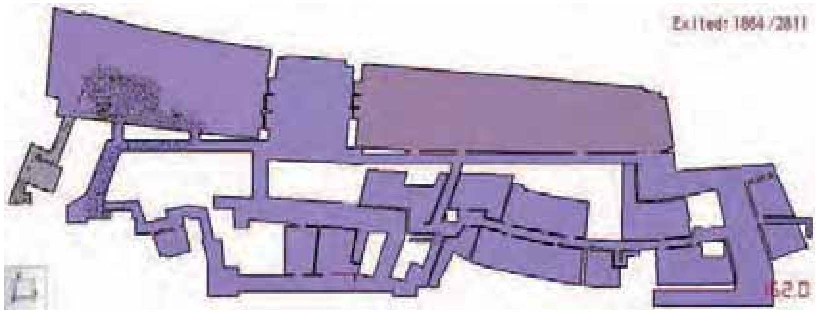


Figure 68 Model geometry showing starting location of occupants on the mezzanine floor

I.6.2 Modelling results

Timeline	Mezzanine floor
30 seconds (0.5 minutes) Occupants begin to evacuate towards their nearest exit including the horizontal exit from the southern pre-function area to to the adjacent northern fire compartment.	

Timeline	Mezzanine floor
60 seconds (1 minute) Occupants begin queuing at exits.	
120 seconds (2 minutes) Occupants continue to queue at the exits. The majority of occupants have from the southern pre-function area have evacuated the mezzanine floor.	
162 seconds **(2.7 minutes)** Occupants from the southern pre-function area on the mezzanine level are considered to have reached a place of safety.	

I.7 Movement modelling – scenario 2 – northern pre-function

I.7.1 Model geometry and occupant distribution

Figure 69 Model geometry showing starting location of occupants

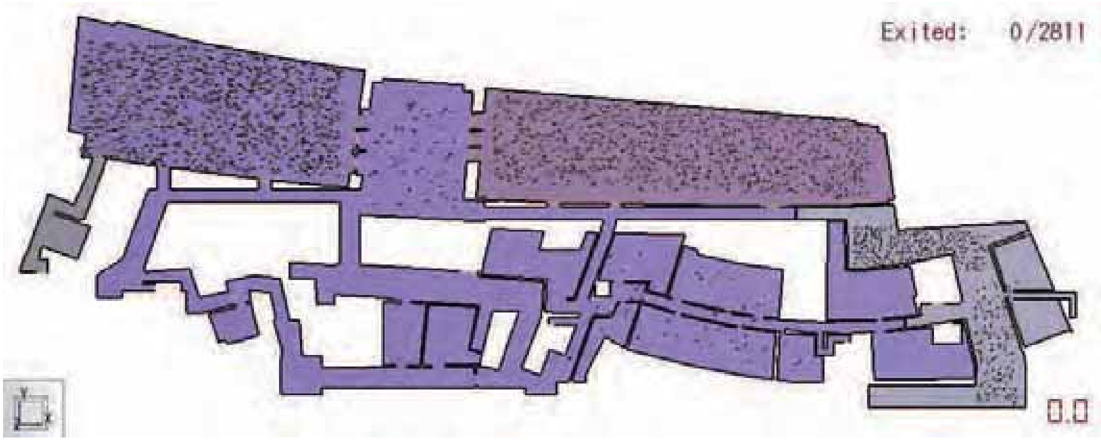
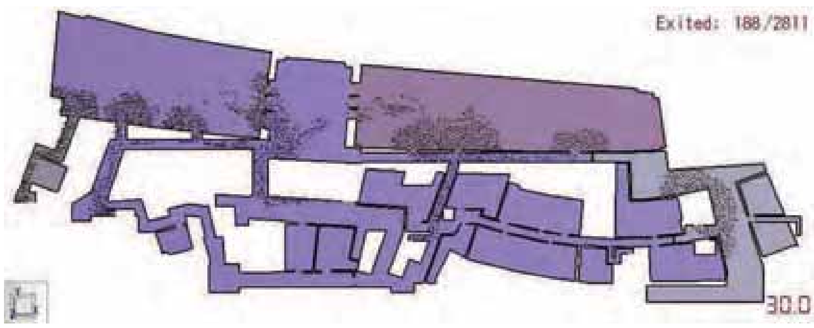
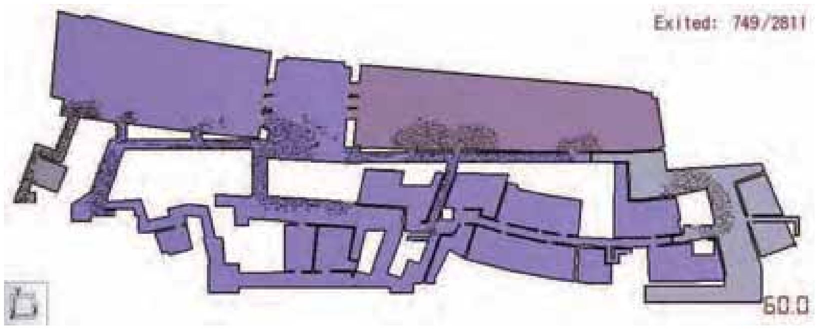
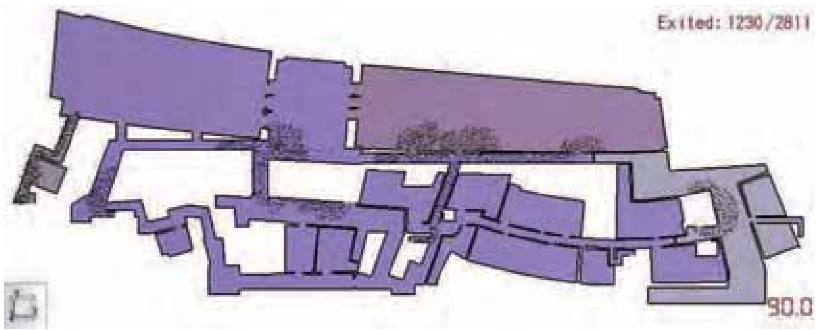
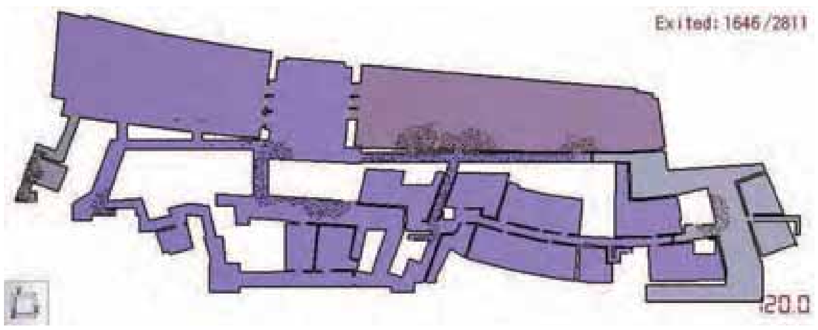
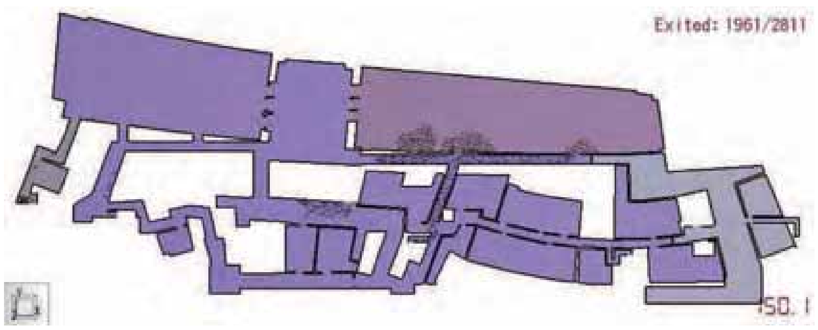


Figure 70 Model geometry showing starting location of occupants on the mezzanine floor

I.7.2 Modelling results

Timeline	Mezzanine floor
30 seconds (0.5 minutes) Occupants begin to evacuate towards their nearest exit. The horizontal exit from then northern pre-function area to the adjacent fire compartment is considered blocked.	

Timeline	Mezzanine floor
60 seconds (1 minute) Occupants begin queuing at exits.	
90 seconds (1.5 minutes) Occupants continue to queue at the exits.	
120 seconds (2 minutes) Occupants continue to queue at the northern feature stair.	
150 seconds (2.5 minutes) Occupants from the northern pre-function area on the mezzanine level are considered to have reached a place of safety.	

I.8 Movement modelling – scenario 3 – southern function

I.8.1 Model geometry and occupant distribution

Figure 71 Model geometry showing starting location of occupants

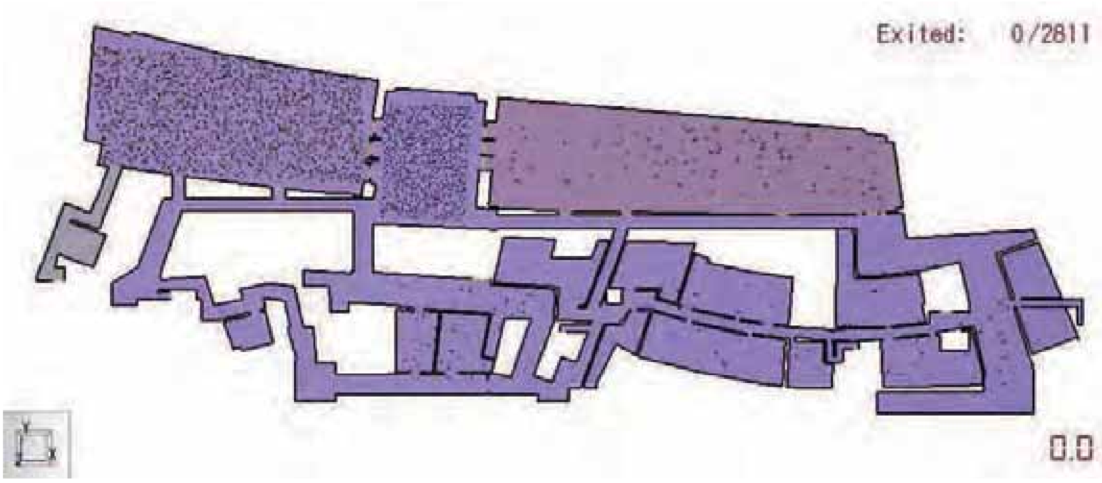
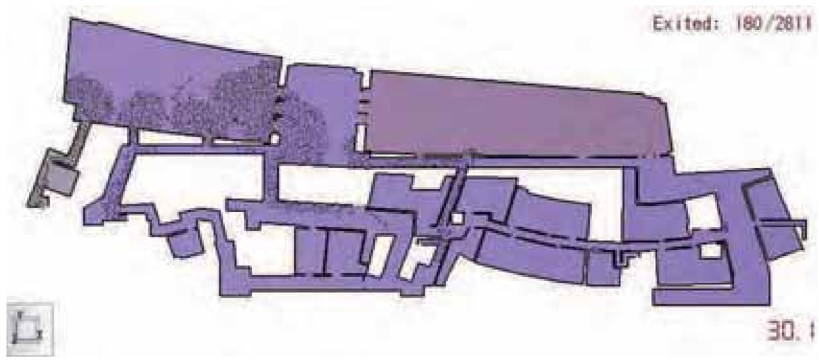
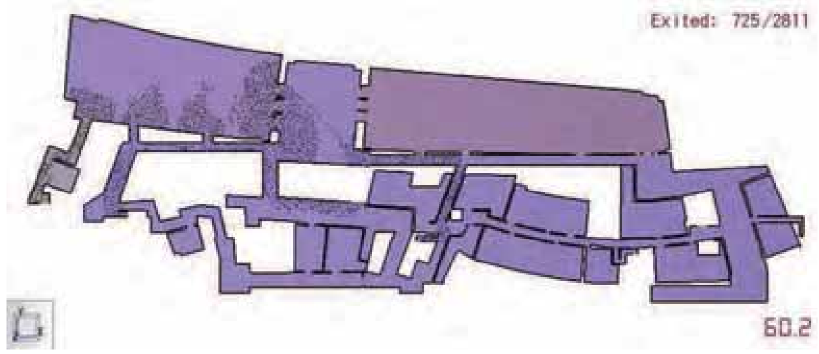
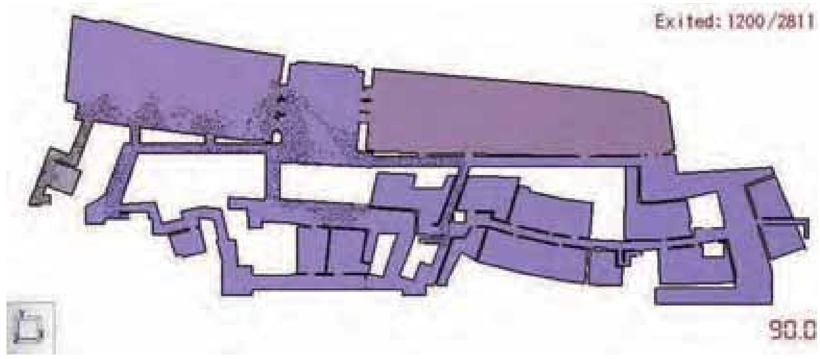
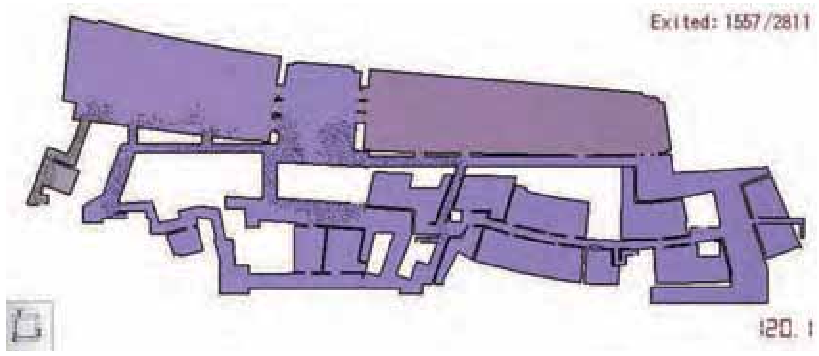
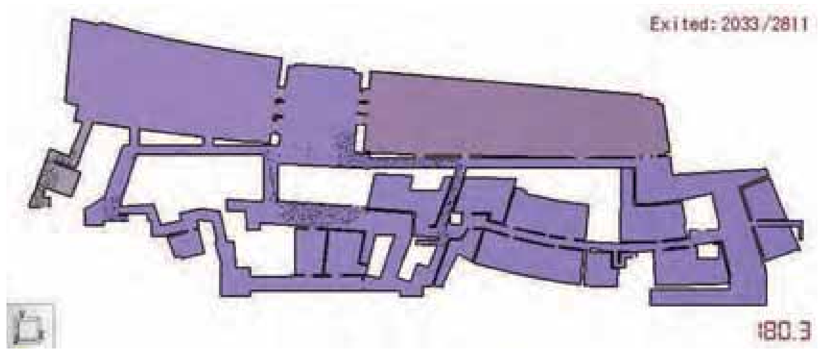
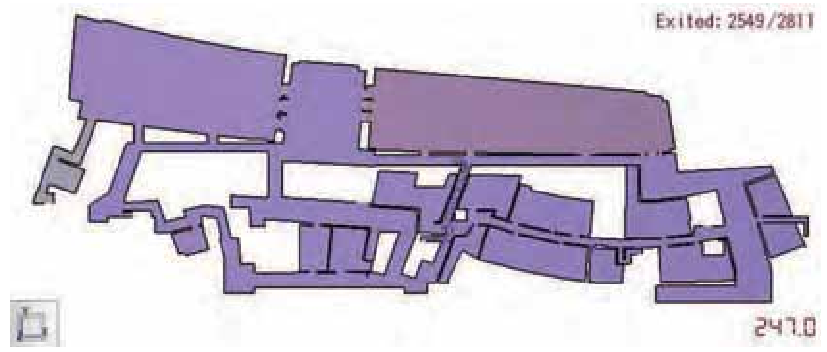


Figure 72 Model geometry showing starting location of occupants on the mezzanine floor

I.8.2 Modelling results

Timeline	Mezzanine floor
30 seconds (0.5 minutes) Occupants begin to evacuate towards their nearest exit. Occupants in the southern function room utilise the horizontal exits to the adjacent fire compartment.	

Timeline	Mezzanine floor
60 seconds (1 minute) Occupants begin queuing at the exits.	
90 seconds (1.5 minutes) Occupants continue to queue at the exits.	
120 seconds (2 minutes) The majority of occupants have evacuated the southern function room fire compartment	
180 seconds (3 minutes) The majority of occupants have evacuated the southern function room fire compartment	

Timeline	Mezzanine floor
247 seconds **(4.1 minutes)** Occupants from the southern function room on the mezzanine level are considered to have reached a place of safety.	

I.9 Movement modelling – scenario 4 – northern function

I.9.1 Model geometry and occupant distribution

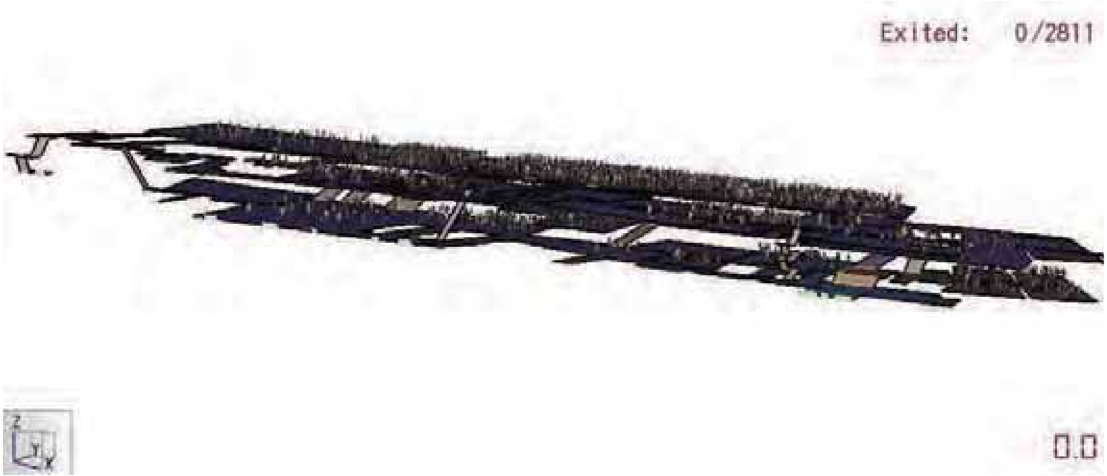


Figure 73 Model geometry showing starting location of occupants

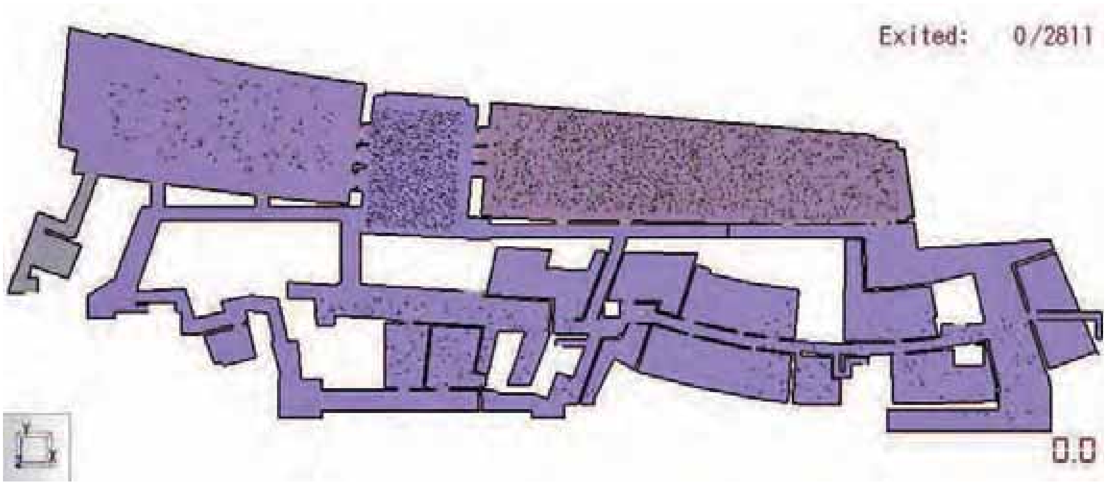
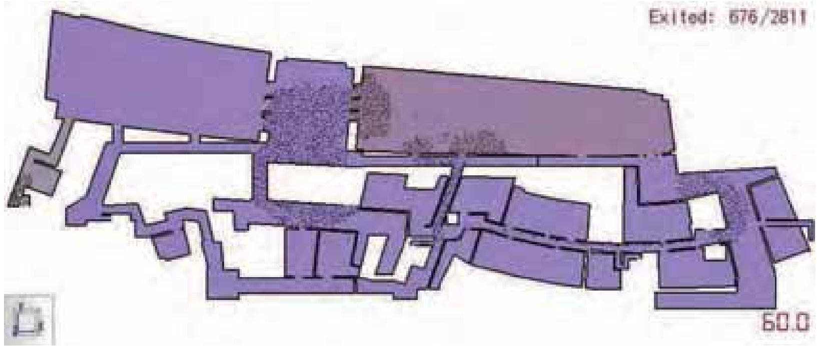
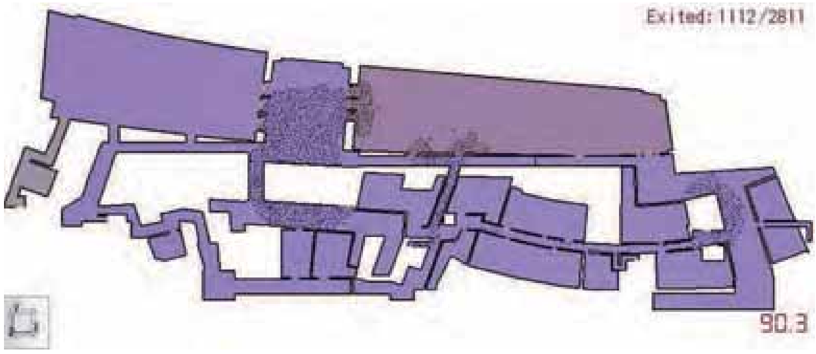
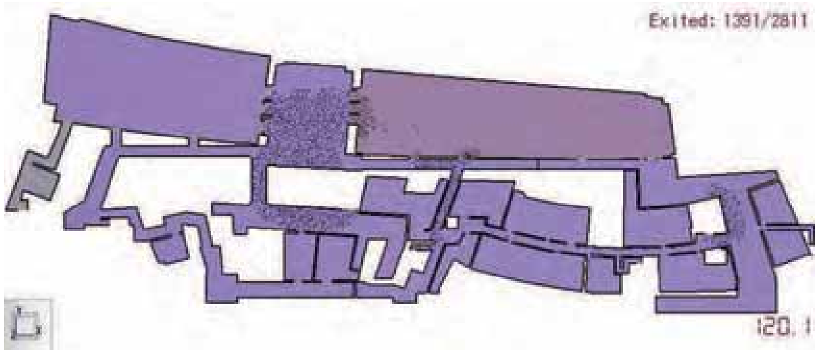
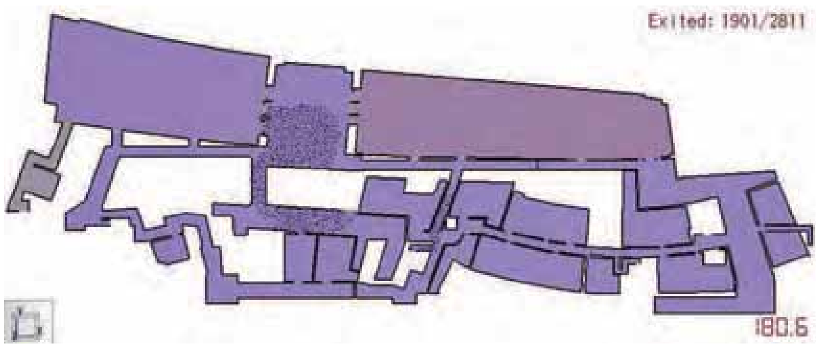
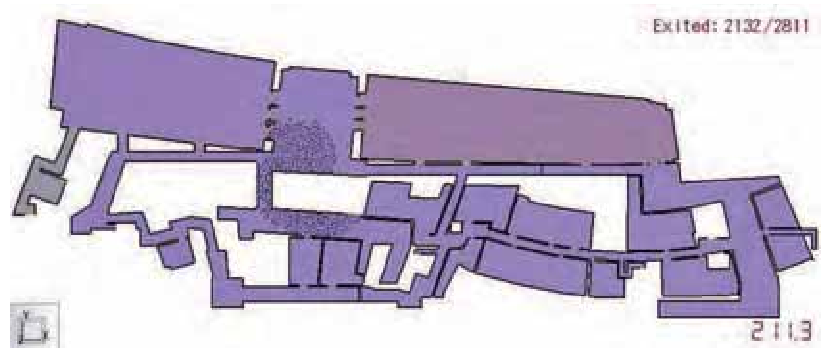


Figure 74 Model geometry showing starting location of occupants on the mezzanine floor

I.9.2 Modelling results

Timeline	Mezzanine floor
30 seconds (0.5 minutes) Occupants begin to evacuate towards their nearest exit. Occupants in the northern function room utilise the horizontal exits to the adjacent fire compartments.	

<table>
<tr><th>Timeline</th><th>Mezzanine floor</th></tr>
<tr><td>60 seconds (1 minute)
Occupants begin queuing at exits.</td><td></td></tr>
<tr><td>90 seconds (1.5 minutes)
Occupants continue to queue at the exits.
The majority of occupants have evacuated the northern function room fire compartment</td><td></td></tr>
<tr><td>120 seconds (2 minutes)
Occupants continue to queue at fire stair 56.</td><td></td></tr>
<tr><td>180 seconds (3 minutes)
Occupants continue to queue at fire stair 56.</td><td></td></tr>
</table>

Timeline	Mezzanine floor
211 seconds **(3.5 minutes)** Occupants from the northern function room on the mezzanine level are considered to have reached a place of safety.	

I.10 RSET summary

The calculated RSETs for the proposed design and the base case are summarised in Table 43.

Scenario	Cue period	Pre-movement phase	Time for last person within compartment of fire origin to reach place of safety (Movement period)	RSET
Base case	92s	Equivalent	254s	**346s**
1. Fire in southern pre-function room (fire compartment 1) – proposed design	48s	Equivalent	162s	**210s (< 346s)**
2. Fire in northern pre-function room (fire compartment 2) – proposed design	48s	Equivalent	150s	**198s (< 346s)**
3. Fire in southern function room (fire compartment 3) – proposed design	48s	Equivalent	247s	**295s (< 346s)**
4. Fire in northern function room (fire compartment 4) – proposed design	48s	Equivalent	211s	**259s (< 346s)**

Table 43 Comparison of RSETs

Appendix J FDS detector activation calculations – alternative solution 2 and 3

J.1 Introduction

The FDS model was developed specifically for modelling building fires. Information on the FDS program has been previously been provided in Appendix F.

J.2 Grid resolution

Based on the information previously provided in appendix F.1.1 and F.1.2 the grid resolution summarised in Table 44 is considered acceptable for the purpose this assessment and provides an appropriate estimation of the overall smoke movement and temperatures.

Using Equation 5 and a fire size of 1MW, the characteristic fire diameter is 0.096m.. A uniform grid size of 0.1m was modelled for the fire region. Although this is higher than the 1/10th characteristic fire diameter, it is considered to provide a reasonable grid resolution as the purpose of the model is to estimate detector activation time and the detectors are located remote from the fire. The aspect ratio of the cells in the models is maintained within the recommended limit of 1:3 in the FDS manual.

Direction	Cell size (m)
x-direction	0.1
y-direction	0.1
z-direction	0.1

Table 44 Grid resolution

J.3 Smoke detection

J.3.1 Smoke detector properties

The time to smoke detector activation predicted by the FDS models has also been used as the cue time for the evacuation calculations.

The Heskestad model was used to prescribe smoke detector properties in FDS. The Heskestad model requires the user to input values for the characteristic length 'LENGTH' and activation obscuration 'ACTIVATION_OBSCURATION'.

The characteristic length represents a transport delay for smoke to move from outside a detector to the sensor. Bukowski and Averill[90] state that the 'characteristic length (L) can be neglected in the room of origin if the detector is in the ceiling jet… elsewhere a default value of 2m could be used in the absence of actual data'. The FDS user manual suggests using 1.8 for unidentified ionization detectors.

The default value of 3.8 for 'ACTIVATION_OBSCURATION' is specified by FDS5. AS 1603.2-1997 – Automatic fire detection and alarm systems – Point type smoke detectors – requires the following range of performance for point type smoke detectors:

[90] RW Bukowski and JD Averill, Methods for Predicting Smoke Detector Activation. Fire Suppression and Detection Research Application Symposium, Research and Practice: Bridging the Gap, USA, NIST, 1998.

TABLE 2.1

SENSITIVITY LEVELS FOR SMOKE DETECTORS

Classification	Sensitivity			
	Value	Nominal (S)	Individual minimum	Individual maximum
Photoelectric	%Obs/m	0 to 15	1.5S or S+2	0.5S or S−2
Ionization	MIC X	0 to 0.4	1.5S or S+0.03	0.5S or S−0.03

Clause 4.10.2 of AS/NZS 1668.1:1998 states that smoke detectors for system control shall comply with the following:

b. Occupied space detectors –

iv. photoelectric – nominal response threshold of not more than 8% Obs/m (AS 1603.2); or

v. ionization – nominal response threshold of not more than 0.4 MIC X (AS 1603.2); or

vi. multi-point-aspirated smoke detectors – nominal response threshold determined for each sampling point shall not be more than 4% Obs/m (AS 1603.8).

Based on the information provided above, a characteristic length of 2 and an activation obscuration of 8 has been used to define the detectors in the FDS models for this assessment.

J.3.2 Modelled paramaters

Smoke detectors have been modelled in a simple square room in FDS which is considered to be a reasonable representation of an open hotel lobby space.

The model had the following characteristics

- Fire properties were as stated in Appendix F.2.2
- 30m x 30m x 2.9m room with all sides OPEN vents

Medium t^2 fire located centrally

Two detectors spaced on the ceiling at AS 1670.1-2004 grid around the fire

Two detectors spaced on the ceiling at AS/NZS 1668.1:1998 grid around the fire

FDS detector properties – L=2 and %OBS = 8

Smoke detectors have been located in the FDS model as shown in Figure 53.

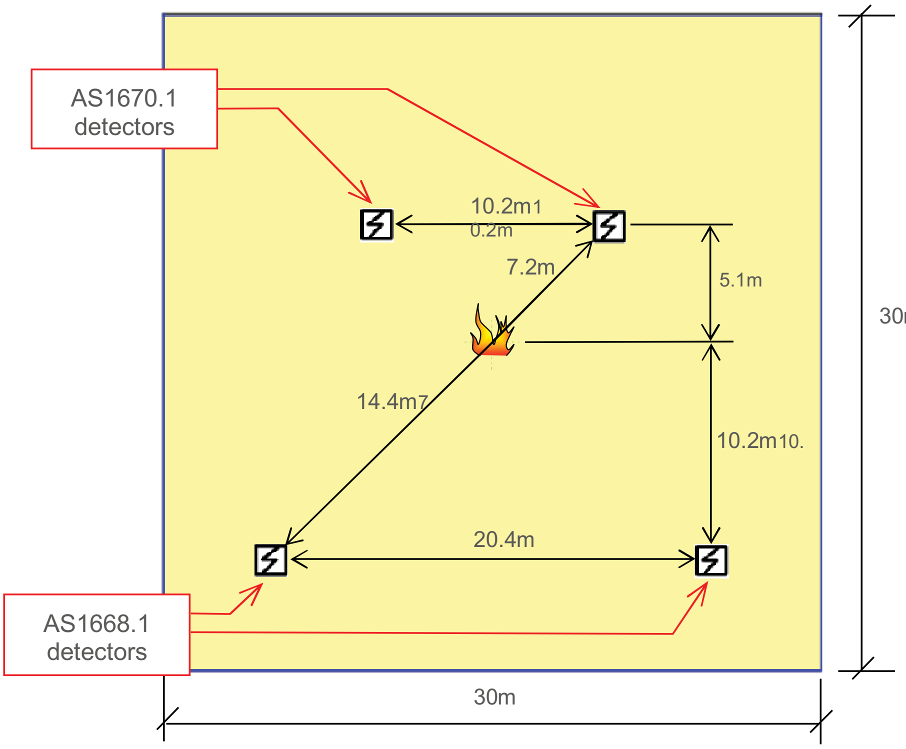


Figure 75 Location of smoke detectors in FDS model

J.4 Results

The output results from the FDS model are summarised in Table 45. The modelling shows that the AS 1670.1 detector spacing in the proposed design activates earlier than the base case. The difference was found to be 44 seconds.

Scenario	Detection method	FDS detector activation times (seconds)	Cue time assumed (seconds)
Proposed design	AS 1670.1 smoke detector 1	48.6	48
	AS 1670.1 smoke detector 2	48.1	
Base case	AS/NZS 1668.1 smoke detector 1	91.6	92
	AS/NZS 1668.1 smoke detector 2	91.8	
Note – Results for multiple detectors have been included where applicable.			

Table 45 FDS detector activation output

Note: The cue time noted for the proposed design was used for the assessment of alternative solution 3 in section 8.