

PERFORMANCE BASED DESIGN

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1. Fire Protection Engineering
2. Performance-based Design
3. Building Codes

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1 Abstract

The project topic is the evaluation of the implementation of Performance-based Design (PBD) in Melbourne, Australia, working with the sponsor, the Metropolitan Fire Brigade. The evaluation came from a series of case studies performed on buildings in Melbourne, as well as interviews of engineers, building owners, and others involved in the building process. From this data, the make recommendations for further research and changes to Melbourne's implementation of PBD to improve safety and communication.

2 Acknowledgements

This project could not have been completed without the advisement of Professor Jonathan Barnett. He taught the team the background we needed in order to perform this research project and also guided us through the project, but still challenged us. He also proved to be a very loud, obnoxious American that got many problems in our building fixed.

The team would like to thank Professor Holly Ault for helping us write our paper and providing us an unbiased and fresh.

We would like to thank the MFB for letting us do our research project with them and we hope they can use what we have done to help the community.

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Finally we would like to thank all the people the team interviewed to get a better understanding of the project and what is happening in the country of Australia. Without their input, the team would not have been able to make collective conclusions due to the limitation of buildings that were visited. This group of people included FSEs, Building Surveyors, Fire Service Personnel, Building Owners, and Building Managers.

3 Table of Authorship

During the preparation of this proposal, the tasks were split up evenly between the three team members, though many of the sections were split up to improve writing efficiency. Research was conducted by all of the members equally for this project, and sources were pooled by the group to allow the group to access all of the research found. In most cases, a team member other than the one that originally wrote a section did the editing, and on many sections, the group discussed the editing together.

The specific sections written by Chris Colschen include the information on Performance-based Design and the advantages and disadvantages of PBD, the section on the fire scenarios and design fires as well as the section on sensitivity of fire models. Chris also wrote the section on British building code implementation and the section of the methodology concerning the case studies.

Alex Cunningham wrote the initial draft of the overall introduction, the introductions to the background and the methodology. In the literature reviews, he focused on the risk vs. hazard analysis section, the Melbourne implementation section, and several of the other building code sections. In the methodology, he wrote the initial draft of the interviews section, as well as some of the areas of interview questions. He spent a great deal of time editing on all the sections of the paper.

Anthony DiOrio wrote the Initial sponsor description, not including the history and included a section on the Problem statement. In the Background portion of the proposal he wrote the intro to Prescriptive codes, Prescriptive advantages and disadvantages, the uncertainties in Performance-based Design, and the Risk Communication section. In the Other Implementation section, he wrote the New Zealand implementation. In the Methodology section he wrote the research goals and objectives. He also added to the initial interview questions.

After the Proposal was submitted, the team performed the remainder of the writing in Australia. These tasks of writing the report, summarizing the case studies, performing the site visits, transcribing the interviews, editing the report, and performing the interviews were split up evenly between the team members. New sections were added to the report by the entire team and editing the sections was an on going process while the older sections, the sections which were evaluated in the proposal, were edited and updated. Editing was extensive and each member of the team edited multiple sections, multiple times.

The case studies were split up evenly as well. Each team member was given one residential building and one commercial building to write up a background summary of the building. This summary included the characteristics of the building, deviations from the DtS requirements, things to look for when visiting the site, and specific questions to ask the manager. The 6 site visits included all the members of the team. Following the site visit each person wrote up a summary of the findings on the building.

All the interviews were conducted by all the team members of the group except for one interview where Chris Colschen stayed behind to finish writing some of the report. Interview transcripts and summary notes were completed by each member while each member did a different number of transcribing and summarizing interviews.

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7 Nomenclature

ABCB – Australian Building Code Board – Creates and maintains the Building Code of Australia (BCA)

Alternate Methods and Materials – An allowance for a version of Performance-based Design mentioned in some prescriptive codes

Alternative Designs – Another term, usually used in prescriptive codes, for a variation on Performance-based Design

BCA – Building Code of Australia – Standard PBD-based building code used in all states and territories in Australia. Needs regulatory approval from each state to be enforced

Break Glass Alarm – This is the equivalent to the United States Pull Station. It is the manual mode of setting off the fire alarm to alert people in a building that there is a fire

Building Code – Requirements that a building must meet at construction in order to be deemed safe to occupy

Building Inspector – The Official who examines a building for fire code violations

Building Regulations – Laws passed by each state that describe the enforcement and specific implementation of the BCA in each Australian state

Building Certifier – General term for the person who performs regulatory evaluations and certifies a building with approval for occupancy; In Victoria, this is the Building Surveyor

Building Surveyor – Victorian official, who may be private or acting on behalf of the city council, who performs regulatory evaluations and certifies a building with approval for occupancy

Deemed-to-Satisfy – (DtS) Provisions in PBD standards that give a series of designs known to be effective derived directly from previously existing prescriptive codes.

Design Fire – The fire characteristics used by FSEs to analysis whether the building meets sufficient safety standards

Deterministic Analysis – a.k.a. Hazard-based Assessment; Uses one canonical fire to determine the effectiveness of the whole fire solution

Essential Safety Measures – A Victorian regulatory term used to describe the safety systems in a building. This primarily refers to purely fire safety systems, such as fire appliances, but can include specific usage requirements as well. These systems are subject to brigade inspection

Fire Appliances – Fire Safety-specific hardware in buildings, such as sprinkler systems, smoke alarms, and hose reels

Fire Brigade – An organized body of fire fighters

Fire Code – Fire safety requirements for a building that apply after construction is complete

Fire Department – Local government body that prevents and puts out fires

Fire Scenario – A hypothetical fire that could occur in a building, used in the analysis of buildings during design and to form the design fire

FPE – Fire Protection Engineer – In the US: engineers that focus on general fire safety throughout many aspects of a building. In Australia: engineers that focus on the design of fire appliances

FSE – Australian equivalent of a US FPE

FRL - Fire Resistance Level – A lab measurement of a building material's resistance to fire, measured in time until the material is compromised

Fuel – Material in a building that is combustible

Hazard Analysis – See Deterministic Analysis

KPI – Key Performance Indicator - Quantifiable measurements of critical success factors used in the fire modeling process

MFB – Metropolitan Fire Brigade – Umbrella organization for fire departments in Melbourne. Also involved in the building evaluation process

MFB Comments – Non-legally-binding suggestions for a building to improve its safety during the PBD process

MFB Recommendations – Legally binding requirements a building must meet to gain MFB approval before it can be constructed

MBS – Municipal Building Surveyor – Employed by the city council, responsible for ensuring both the structural and fire safety of people within buildings in the city

NFPA – National Fire Protection Association – US fire protection standards organization

Performance-based Design – Building code paradigm that gives building designers broad safety objectives and requires an engineer to evaluate the building individually

Prescriptive Codes – Building codes that precisely define requirements a building must meet to pass inspection. These requirements are detailed, and frequently quantitative

Probabilistic Analysis – a.k.a. Risk Analysis – The Analysis technique that uses probabilities of different fire events to determine which ones are most important

Risk Analysis – See Probabilistic Analysis

SFS – Society for Fire Safety, an Australian professional body for Fire Safety Engineers

WorkSafe – Government agency responsible for occupational health and safety

8 Executive Summary

Building fires present a significant hazard in cities, and regulatory officials work to prevent and mitigate these hazards through the use of building codes. In recent years, building codes in Australia and many cities around the world have moved to more flexible Performance-based Design (PBD) techniques to allow for more innovation in building design. This transition poses some risks, however, as PBD requires a Fire Safety Engineer (FSE) to design alternative fire safety solutions and then analyze these systems to determine if they at least meet the minimum expectations of the Building Code of Australia (BCA), which may be less conservative than the Deemed-to-Satisfy (DtS) requirements. These fire safety solutions frequently rely on the implementation of policies by building managers to maintain their efficacy. The goal of this project was to determine, based on real-world examples, whether buildings using PBD have successfully implemented policies that ensure the design assumptions made by the FSE hold true during occupancy. The result is a set of recommendations for further research based on the information gathered during this project.

The effective implementation of these policies depends on the communication between the parties involved in the building process, and can be broken into two sections:

1. Downstream Communication – the flow of fire safety information from FSEs through to building owners/managers in order to determine what policies to implement and the role they play in keeping their building safe.
2. Upstream Communication – the flow of usage information from building owners/managers/maintenance to the designing FSEs in order to determine what assumptions can be made about building usage within design models.

The methods for evaluating this communication were broken into the two main research objectives for the project:

1. Determining whether usage assumptions underlying the fire engineering models were correct in the building during occupancy.

2. Determining whether building managers/owners were aware of the effect usage changes can have on the fire safety systems and how to avoid these changes.

Performing this research consisted of two parts: a series of detailed case studies conducted on buildings in Melbourne, and interviews of FSEs, Fire Services Personnel, Building Surveyors, and Building Managers/Owners. The case studies provided concrete examples of PBD implementations and the interviews allowed an evaluation of the communication between stakeholders. The building managers/owners from each case study building were questioned specifically about policies concerning the PBD fire safety systems, and these answers were compared to the results of the site visits of the buildings themselves. The remaining interviews were performed to provide an account of the experiences of various stakeholders involved with the design process. The groups were compared against each other to determine the effectiveness of the communication in the building process.

During the course of the project, the team visited six buildings for use as case studies with three residential apartment buildings and three commercial warehouses. In these samples, the level of compliance with usage specifications from the fire engineering reports varied from buildings with significant usage deviations that could catastrophically affect fire safety to buildings that were rigorously managed and able to detect and compensate for changes quickly. It should be noted that there were not enough case studies to be able to generalize the distribution of flawed buildings over Victorian buildings.

From these case studies and interviews, it was determined that there are issues with the implementation of PBD in Melbourne. Although the sample size was small, the problems found in these buildings combined with experiences of interview subjects indicates that there are a substantial number of buildings that are not being used and maintained as specified by the FSE during the fire analysis. Additionally, the team found that:

- There is no mechanism in place for detecting subtle changes in a building's use that don't necessarily change its classification.

- Many issues found were not necessarily a result of PBD, but the severity of the issues was often compounded as a result of the alternative solution removing redundant systems.
- FSEs have little to no involvement with the project after the fire engineering analysis is complete.
- There are not enough enforcement officials to be able to effectively police all the buildings in Melbourne. Instead, regulatory bodies are focus on high risk buildings and rely on complaints to catch issues elsewhere.
- Building managers rarely have any technical knowledge of the fire safety requirements, including those whose buildings are well run and compliant.
- Most building managers are dependent on outside contractors to perform maintenance on fire safety systems.
- Some owners and managers see no financial benefit to performing maintenance as the fines for getting caught are less than the maintenance costs.

Based on these findings the team made several recommendations, both for further research and to improve the implementation of PBD. As the sample size for this study was too small to make any generalizations on the extent of implementation issues, it is recommended that further studies be performed on a larger sample of buildings. Of particular interest should be buildings which have experienced change in ownership, as this was indicated by virtually all the interview subjects as a scenario when information can be lost and usage can change. Additionally, older buildings should be examined since the only PBD buildings available at the time of this project were relatively new. The goal of these studies should be to determine the level of compliance and to determine what, if any, usage assumptions tend to not be implemented. Research should also be done to determine how well fire safety system maintenance companies perform their duties.

Additional recommendations include the following:

- Evaluating maintenance contractors could show a positive response. Building owners and managers can use this information to hire the best maintenance contractors to ensure the compliance of the building's safety systems.

- Fines for failing to properly maintain should be increased to make it in the managers' financial interest to meet the requirements.
- Efforts should be made to educate owners, managers and insurance companies about fire safety and how to keep a building safe. The insurance companies, in particular, if it is shown to be in their best interest, can be used to enforce fire safety regulations.
- Fire safety requirements need to be communicated more clearly and understandably to building managers. This can be done either through a more standardized format for the occupancy permit or through a separate set of operating manuals detailing how the building needs to be managed.
- Companies should look into more self-policing policies.
- FSEs should be more involved in the actual construction and commissioning of a building. One way to do this would be to require the signature of the FSE on the occupancy permit for buildings using the alternative solutions he designed.

9 Introduction

Fires present a significant hazard in large cities, as large buildings with many occupants make dealing with fires more complicated. Fires are destructive not only through loss of life, but also through significant property damage and economic consequences due to a lost business, lost records and replacement of damaged goods. In the US, in 2005, there were 511,000 structure fires, with over 3,000 civilian deaths, over 15,000 injuries, and US\$9.2 billion in property damage (National Fire Protection Association [NFPA], 2006). In New South Wales, Australia, there were 7259 building fires from 1997-1998 which caused 531 injuries and 27 deaths, as well as more than AU\$241 million in damage (New South Wales Fire Brigade [NSWFB], 1998). The public as a whole feels the cost of severe fires, as insurance rates must take into account the cost of rebuilding the damaged or destroyed buildings.

Fire Safety Engineers¹ (FSE) work to prevent deadly fires by determining the best ways to construct and maintain buildings with performance during a fire in mind. Australia has implemented a Performance-based building code, in which designers are given broad performance requirements that a building must meet in order to accomplish certain objectives. In the construction of large buildings, such as schools, offices, and apartment complexes, designers may consult with FSEs to ensure the fire safety systems in the building will meet these performance requirements. With Performance-based Design (PBD), designers have increased flexibility to use alternative designs to accommodate unique circumstances or the use of innovative materials and methods (Australian Building Codes Board [ABCB], 2004). While PBD allows for greater flexibility of design, it relies on assumptions made by the engineer during the design process. Small changes made by the occupants of the building can dramatically change the validity of these assumptions, often without the occupants even realizing it. This can result in discrepancies between the models designers use to predict fire performance and the actual usage of the building (Marchant, 2003).

¹ The terminology for this position differs between the US and Australia; in the US an engineer that focuses on general building safety in a fire is a Fire Protection Engineer (FPE), while this same position in Australia is a Fire Safety Engineer. Because this paper focuses on Australian fire safety, the convention will be to use FSE in all cases.

At the core of the discrepancies between a building in use and its PBD models is knowledge transfer amongst the key parties involved with the building. In order to ensure the assumptions made by the designers are valid and continue to be valid throughout the building's lifetime, communication between key stakeholders, specifically the designers and occupants, must be maintained. Those who actually live in, work in, own and maintain a building must know how to ensure the building continues to meet the fire performance specifications of the designer. In the information passing from the users through to the FSEs, the building designers should know whether usage assumptions made at design-time are accurate based on the real-world usage of the building. By maintaining the transfer of knowledge amongst all involved parties, the discrepancies between the designer's fire performance models and the building in use can be reduced to improve safety.

The implementation of PBD evaluated in this project was the Melbourne implementation covered by the Metropolitan Fire Brigade (MFB). The MFB statutory authority is throughout Melbourne, which limited the sample size of the study to a pool of buildings in Melbourne. However, the area covered by the MFB is large, with over 1,000 square kilometers, \$200 billion in assets, and over 3 million people ("Corporate action plan"). The findings of this research could have wide-reaching implications, as modifications to building codes and the laws that authorize their enforcement affect a very large number of buildings. Furthermore, the data from this project could be passed on to national agencies that deal with building codes as well, which means that results of this project could have an effect on the implementation of building codes across a much larger region than that which the MFB oversees. The results could be applicable anywhere PBD is currently implemented or where there are plans to implement PBD.

The background research consisted of an examination of the performance-based building process as implemented in buildings from design through to final use of the building years after completion. This required an understanding of fire safety engineering as applied to the design of buildings and an understanding of the occupant usage data designers use to create engineering models. At the other end of the spectrum, it was important to understand what occupants, owners and

maintenance staff of buildings should know about fire safety. In order to understand the sources of discrepancies between a building's use and its design, the project required analysis of the competing needs in the development of a building, such as economic concerns or long-term usefulness. This gave sufficient background on each node in the knowledge transfer chain to start on the project itself.

There were two main research objectives in evaluating the implementation of PBD in Melbourne: determine the existence of changes in building use that have invalidated the FSEs' fire model for the building, and determine the level of awareness of these changes among the people who own, maintain and occupy the building. With the data from these research objectives, common areas of discrepancy were found and recommendations were produced to improve the implementation of PBD in Melbourne. The primary source of research for this project consisted of a series of case studies performed on a pool of buildings in Melbourne. MFB selected these buildings as ones that make use of PBD, and all buildings were assumed to have met code at the time of construction.

The case studies themselves accomplished the first research objective: finding discrepancies between the buildings, if any existed, and their documented performance specifications. This consisted of building visits with inspectors from MFB to determine how well buildings continued to meet the fire performance specifications documented during the design and construction of the building. This provided a direct test as to how much buildings in the case studies diverged from their original planned use. The second research objective, finding the level of knowledge among those who own, maintain and occupy the building, was accomplished by interviewing these people to find out how aware they are of how their actions can change these assumptions, invalidating the design models and possibly making the building less safe.

After a suitable number of case studies were completed, the data was analyzed to determine common areas of discrepancy and their sources. Due to the small sample size of the buildings examined during this project, it was not possible to do a full statistical analysis and generate trends. Even with this limitation, the sample size was sufficient to find several common areas to improve. The most important part of

the project was creating a list of recommendations for improvements to be made in the existing system and areas for more research. These recommendations included things such as simple changes to building codes or procedures, or even legislative changes. In any case, there exists room for this project to have a significant effect on the implementation of PBD in Melbourne and in many other cities.

10 Background

The manner in which building and fire codes are applied is a complicated process, involving a number of different parties and constraints. This section seeks to give a background on design techniques used in the development of buildings, particularly those concerning regulatory influence. There are two essential paradigms used in building codes aimed at fire safety: prescriptive codes and Performance-based codes. Prescriptive codes give a very precise, methodical list of (frequently quantitative) requirements for a building design to follow, whereas Performance-based Design (PBD) give broader safety objectives to meet with the requirement that a Fire Safety Engineer (FSE)² analyze the building.

Prescriptive codes have been around much longer, but in recent years many jurisdictions have moved over to PBD because of the potential advantages in cost savings and enhanced flexibility. This transition is still a recent event and there are many aspects of the implementation of PBD that need to be evaluated. One of the major issues is the effect of subtle usage changes to the design fire's underlying assumptions, which are unlikely to be perceived as significant, that can have an effect on the effectiveness of the building's fire safety systems. This can be due to issues with the assumptions used during design of the buildings, or building occupiers not knowing what is necessary after construction to keep the building safe.

The purpose of this research project is to evaluate the Melbourne implementation of PBD by determining if those buildings constructed under PBD have any of the subtle flaws that might undermine their safety and whether those people who own, occupy and maintain the buildings know how to avoid these subtle flaws. Subtle flaws are the focus of this project due to the fact that more substantial changes will require building recertification and thus, design reevaluation.

² The terminology for this position differs between the US and Australia; in the US an engineer that focuses on general building safety in a fire is a Fire Protection Engineer (FPE), while this same position in Australia is a Fire Safety Engineer. Because this paper focuses on Australian fire safety, the convention will be to use FSE in all cases.

Performing this evaluation requires background knowledge of how building codes work, starting with prescriptive codes and the transition into PBD. Because the focus of this project is on the implementation in Melbourne, knowledge of some of the legislative and regulatory influences on the use of building codes is necessary. To see how Melbourne's implementation compares to the rest of the world, the building code implementations from several other areas in Australia and other countries are included.

10.1 Prescriptive Design

Prescriptive design is the predecessor to PBD in the world of fire safety. Gaining an understanding for the older prescriptive codes can provide a better outlook on PBDs. Supplying the advantages and the disadvantages of the prescriptive codes will help explain why Performance-based codes are being adopted by many countries.

10.1.1 Prescriptive Codes

A prescriptive code specifies “certain construction characteristics, limiting dimensions, or protection systems without referring to how these requirements achieve a desired fire safety goal” (SFPE 9). An example of a prescriptive code from the Florida Building Code concerning automatic sprinklers states for a certain classification of building, based on the building's intended use, an automatic sprinkler system must be provided if:

- The fire area exceeds 12,000 square feet (1115 m²).
- The fire area has an occupant load of 300 or more.
- The fire area is located on a floor other than the level of exit discharge.
- The fire area contains a multi-theater complex (Florida State Legislature)

This code is very representative of the typical prescriptive code. It gives a very clear description of exactly how to satisfy the requirement. If the building meets any of the criteria it must have a sprinkler system, otherwise it is not necessary. The reasoning behind the requirement is not made clear, nor is the goal of the code.

10.1.2 Building Process

The building process can be broken down into a series of phases for a building engineered for fire safety. The following is a generalized description of how the

building process should proceed based on the Fire Safety Engineering Manual of Practice (Ramsay, et al., 0.2-3). This is an idealized version of the building process and the areas in which flaws arise will be covered in Section 10.2.4. This description is not specific to any particular locality, and should only be considered to be a benchmark for comparisons.

In the initial design phases, implementing fire safety solutions is easiest. As there is a great deal of flexibility at this stage, multiple methods of developing the building for fire safety can be evaluated to determine which are both effective at preventing severe fire and cost effective. The designers have the choice of using either the ‘Deemed-to-Satisfy’ designs, or finding an alternative design through a PBD process. ‘Deemed-to-Satisfy’ designs are prescriptive requirements listed in the building code known to provide an acceptable level of safety by meeting the performance objectives. These provide precise design parameters that can be directly implemented. If there is another safety solution that can provide a comparable level of safety, then it can be implemented with PBD. The PBD process, described in greater detail in Section 10.2.1, but for the purposes of this section, both prescriptive and PBD solutions are available to implement. These alternatives could use non-standard materials, equipment, or other design techniques that could provide an equivalent level of safety at reduced cost. The use of Performance-based alternatives will be detailed in Section 10.2 (Ramsay et al. 38).

The next phase is regulatory approval, where a reviewing FSE must approve the design or be sent back for changes. Upon granting initial regulatory approval, the construction phase begins. The construction phase still requires the input of an FSE to ensure any changes to the design do not impair the effectiveness of the fire safety systems (Ramsay et al. 38).

After construction, the building goes through a commissioning process in which a building certifier must test the final building for code compliance before occupancy. This process can include actual tests of the fire safety systems implemented in the building, and these tests should also include integrated testing to determine how well multiple systems function together. In the case of a Performance-based alternative design, an FSE will need to set the necessary performance

requirements used to measure the specific system in the building. Once the tests are complete, the building receives an occupancy permit certifying it is ready for use. During the occupancy of the building, the information used in the fire planning must reach the owners and occupants of the building, so usage, fuel load, and fire safety system assumptions made by FSEs to model likely fire scenarios are not invalidated inadvertently. Even something like rearranging furniture could have an adverse effect on the fire performance of a building because the fuel load could change or evacuation routes could be impaired, resulting in a fire the FSEs had not anticipated. The building managers should receive a series of guidelines that explain how to properly maintain the building. Further in the life of the building, should the use of the building change, or alterations be made to the building, managers should consult an FSE to ensure the building remains well-protected from fires (Ramsay, et al., 0.2-5 – 0.2-6).

Because there is more to the building than the fire safety systems, it is helpful to understand some of the parties and processes involved with the construction of a building. The party that usually starts the building process is the developer, which usually finances the building, assembles the design team, oversees the building through construction, and in many cases, sells the building. This is the party that is most directly connected to the design process, although eventual owners of a building are frequently included in order to ensure it meets their needs. After construction, the developer hands the building over to the owner, which may be a single person or small business or a large corporate entity that owns many buildings. The management of the actual building may not be involved in the design process, and will depend on the exact use of the building (Edwards).

10.1.3 Advantages of Prescriptive Codes

Prescriptive codes have been enforced for generations; only in the last decade or so has the PBD approach been implemented. Prescriptive codes still work as a safety measure in many places, including the United States of America where the transition to PBD has been slow. There are several advantages to prescriptive codes that also explain their continued use. If a building has certain occupancy and a certain square footage, then that building automatically falls under a particular set of codes

and standards requiring the building include certain fire safety features. This is an advantage when the construction of a building is underway because there is no analysis to conduct, the designers merely have to categorize the building appropriately and follow the applicable codes (Babrauskas).

Another advantage to prescriptive codes is they provide a high level of fire safety in buildings following common 'standard' design patterns. Prescriptive codes stipulate specifically what to do in each case with a minimum of interpretation. Prescriptive codes are also easy to enforce as there is no inherent analysis that must occur in order to apply them; code enforcement officials can simply check certain measurements and specifications off on a list (Barnett). This makes it easy to determine if a prescriptive code has been met or not. The codes are not perfect, however, which explains the continuing trend toward the newer PBD (Babrauskas).

10.1.4 Disadvantages of Prescriptive Codes

The primary disadvantage of prescriptive codes is the lack of flexibility. The inflexibility of prescriptive codes is largely due the very specific quantitative requirements often prescribed in the codes. The inflexibility of prescriptive codes leads to a range of problems. One problem is that the designs produced are not always the most cost-effective, as prescriptive codes may not allow the use of possibly cheaper alternate design solutions. While specific requirements can make the design of more 'standard' buildings easier, buildings that fall outside of the common design patterns are made more difficult. Some more unique buildings, such as skyscrapers or large stadiums, simply cannot be built easily under prescriptive codes because the codes simply do not cover such buildings. Because of their size, the emergency planning for these special case buildings needs to take into account complexities that are covered in prescriptive codes. These problems make the use of prescriptive codes more difficult or impossible in some situations (Hadjisophocleous and Bénichou 127-142).

10.2 Performance-Based Design

The movement towards PBD began in the 1970s with the development of the concept. In the 1980's, individual nations began implementing a Performance-based building code, with Great Britain and Japan being among the first to attempt to incorporate elements of PBD into their respective building codes (Barnett; The Evolution of Performance-Based Codes 4). Performance-based codes were implemented to address some of the main disadvantages of prescriptive codes. This section will define PBD and outline the design process as well as some of the advantages and disadvantages of PBD.

10.2.1 Performance-Based Design Description

Performance-based codes can be defined as codes or standards that specifically state their goals and reference acceptable methods to demonstrate compliance with their requirements (SFPE 8). In contrast with prescriptive codes, Performance-based codes identify objectives to meet and define possible methods of satisfying the objective without limiting the designer to any specific solution. Any method that satisfies the performance requirements outlined by code is available for use (About the Building Code).

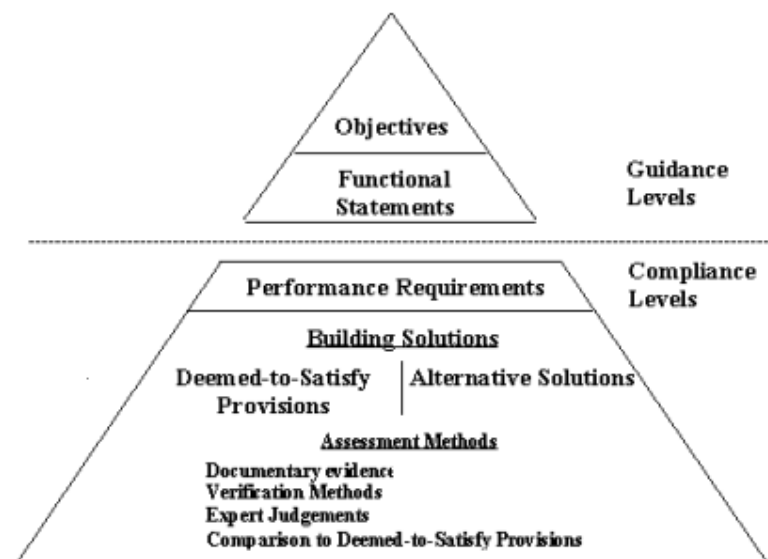


Figure 8-10-1: Hierarchy of the BCA (“About the Building Code”)

Figure 8-10-1 shows the performance hierarchy of the Building Code of Australia (BCA). Moving down the pyramid it is easy to see how performance-based codes are written and implemented in a general sense. At the top of the hierarchy are the objectives, which are general statements of what the designers must accomplish. These are stated in very broad terms, leaving the details of achieving this goal to lower levels in the hierarchy. Table 8-1 shows specific examples of the top three levels of the pyramid. A typical objective might state that occupants should be kept safe in the event of a fire. The functional statement then gives a general statement of how to meet the objective. A possible functional statement for the previous example would be that a building must be constructed to prevent the spread of fire long enough for occupants to safely evacuate. The next level of the pyramid specifies the performance level the building must satisfy. The performance requirement is mandatory and must be satisfied either through the use of the Deemed-to-Satisfy provisions or alternative solutions (About the Building Code).

Objective	Functional Statement	Performance Requirements
Protect the occupants not intimate with the initial fire development from loss of life	A building is to be provided with safeguards to prevent fire spread so occupants have time to evacuate to a safe place without being overcome by the effects of fire	A material and assembly must resist the spread of fire to limit the generation of smoke and heat, and any toxic gases likely to be produced, to a degree appropriate to the travel distance, the number and mobility of occupants, the building use and the active fire safety systems installed in the building

Table 8-1: Example of Objective, Functional Statement and Performance Requirement (Custer and Meacham 72-73)

Deemed-to-Satisfy provisions are written similarly to prescriptive codes. They outline a specific requirement the building can meet in order to satisfy the performance requirement. The building designer can choose to meet this provision or use an alternative method so long as it can be proven to satisfy the performance requirement through one of the assessment methods (About the Building Code).

The goals of Performance-based codes, specifically with regard to fire, are relatively simple and straightforward. The most important goal is widely considered to be the protection of the lives of the occupants. This means people must be alerted to the danger and must be allowed enough time to evacuate safely to a safe location. Performance-based codes must also include provisions to prevent the spread of the fire. In Australia, this goal only applies to the spread of fire to other buildings. There are no provisions in the BCA to protect the building in which the fire originated except for the purpose of suppressing the fire in order to allow the occupants enough time to escape. Any concern for the building itself is limited to protecting the

occupants and nearby buildings. The owner of the building might specify additional performance requirements to limit damage but these are separate from the BCA requirements and not subject to enforcement from the government. Lastly, it is the goal of Performance-based codes to protect firefighters while they do their job. This includes ensuring the structural integrity of the building so it can withstand the fire long enough for firefighters to perform search and rescue operations (Barnett; Bukowski 81).

10.2.2 Fire Analysis

In order to perform evaluations of PBD implementations, it is necessary to understand some of the underlying technical components of producing a PBD. While this project will not focus on the technical details concerning fire models and the scientific background material, it is useful to understand many of the basic components of fire safety.

10.2.2.1 Risk vs. Hazard

In order to effectively evaluate a specific PBD, some attention needs to be paid to exactly how engineers assess safety in a building. Because reducing a building to a mathematical model is a very complicated process, there are several ways of approaching the problem. There are two basic paradigms in assessing a building design's effectiveness; however a combination of both often provides the best analysis.

One method of analyzing a building is a deterministic approach, which relies on scientifically derived mathematical models that can describe the progression of a fire. There is a wide variety of different models that can be applied to buildings and particular conditions, so it is easy to tailor models to a particular building. One advantage of this approach is the outcome of the models is determined completely by its parameters, so the results of a simulation will always be the same if the parameters are the same. The abundance of models is the reason deterministic assessments are more frequently used (Metropolitan Fire Brigade).

Deterministic assessments are also known as hazard-based assessments, where the analysis focuses around a single canonical fire to determine the performance of the whole solution. The biggest flaw with a pure hazard-based assessment is it centers on a specific fire, which may not fully test the other aspects of the design necessary for a more thorough performance analysis (Bukowski and Babrauskas 173-191).

Another method of analysis is a probabilistic assessment, which centers on calculating the risk associated with design elements and determining the probabilities of certain events occurring over time. The advantage with probabilistic approaches is the method also gives the probabilities of fire contingencies. The difficulty with this approach, however, is the data necessary to make probabilistic comparisons are very difficult to acquire in sufficient detail to be effective, which is why probabilistic assessments are not used as frequently (Metropolitan Fire Brigade).

The probabilistic assessment is also known as a 'Risk-based' assessment, named because one must attempt to find and sort all the possible risks that could occur in a particular building, and then rank them. This ranking allows the engineer to determine the acceptable 'cost' in the case of a fire. This is a particularly difficult area of this form of fire assessment, because there are costs which cannot be easily compared, such as property damage vs. human life. There are other difficulties here as well, as determining the list of all events that could occur (even very unlikely or unusual ones) is very hard (Bukowski and Babrauskas 173-191).

In order to manage the problems of both approaches, it is necessary to use a mixed approach that examines multiple fire scenarios to ensure all the various parts of the design solution are examined. Risk-based analysis should be used to determine what fire scenarios are the most likely. This provides a way of managing the benefits of both assessment strategies while mitigating the negative effects (Bukowski and Babrauskas 173-191).

10.2.2.2 Fire Scenarios and Design Fires

A key part of the fire safety design process is the creation of the fire scenario and design fire. A fire scenario is a description of a specific fire including specific building features and the damage the fire is expected to cause (Custer and Meacham 43). A design fire is a “set of conditions that defines or describes the critical factors for determining outcomes of trial designs” (SFPE 7). Fire scenarios are defined first in the design process, and then used to create design fire scenarios, which are in turn used to evaluate possible designs. This relationship is shown in Figure 10-2. This section will describe in more detail this process and the decisions that must be made regarding key assumptions about the fire, building, and occupants.

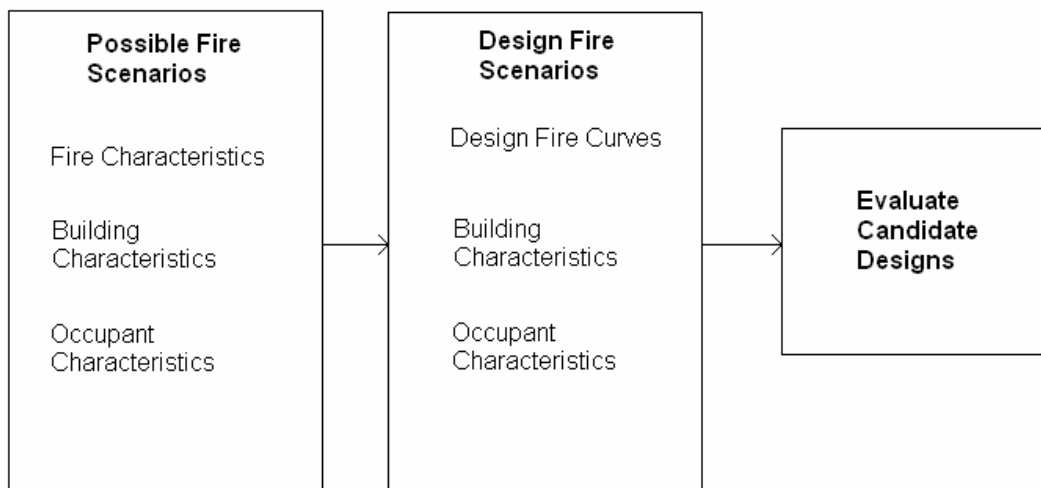


Figure 10-2: Design Process

The development of fire scenarios is the first step in determining how to satisfy the performance criteria outlined in the building code. In order to determine possible fire scenarios, the pre-fire conditions of the structure must be determined. These conditions fall into several categories. One is building characteristics. This includes factors such as the size of the rooms, the amount of ventilation through doors, windows and other openings, the height of the building and the proximity of the building to other fire hazards such as neighboring buildings. The fire protection systems such as sprinklers and smoke detectors must be taken into account as well as the amount of fuel (combustible materials) in the building, the response of the fire department and the environmental factors such as temperature and humidity. These are just some of the building characteristics to consider in the fire scenario. In many cases, these factors are not explicitly known and assumptions must be made (Custer and Meacham 44; National Fire Protection Association 25; SFPE 42-55).

The fire scenario must also take into account the occupants. The response of the occupants to the fire is important and is generally dependent on the ability to sense physical cues, such as smoke or a fire alarm, the ability to interpret these cues and react appropriately, the mobility of the occupants, and their susceptibility to the heat and toxins produced by fires. These characteristics might include the occupants' familiarity with the building, which affects their ability to react appropriately, the alertness of the occupants, such as whether they are asleep or awake, and how committed the occupants are to their pre-fire activities, which could affect their willingness to leave the building. Group dynamics also play a role; such as whether a person will lead or follow and whether a person will respond as a member of a group or as an individual. The fire scenario must also take into account evacuation times and other psychological factors such as fear and panic (Custer and Meacham 46; National Fire Protection Association 24; SFPE 55-57)

Finally, designers must consider the characteristics of the fire. One such consideration is the source of ignition. The initial fuel is also an important factor. The state of fuel, which affects how easily it is ignited, what that fuel is made out of, the quantity of fuel, and the arrangement of the fuel in the room are critical to the development of the fire. The ability of the fire to spread beyond the area in which it starts is important as well as the location of key features, such as critical documents that must be protected, specified by the client with relation to the initial fire location. These are all factors that must be considered in the creation of fire scenarios (Custer and Meacham 44-46; Ramsay et al. 2.2 3-4; SFPE 57-62).

These characteristics are used to determine possible fire scenarios using several methods. One such method is called Failure Modes and Effects Analysis (FMEA). This involves studying the possible failure modes of individual components and the cause and effect of each possible failure mode. Failure analysis is another method, which involves identifying possible causes of unacceptable losses as defined by the stakeholders in the building process. These losses might include death, injury or other possible outcomes of a fire. Fire scenarios can also be identified through simple "what if" analysis by determining the outcome of a certain failure or event.

Using these methods and others, possible fire scenarios can be determined (Custer and Meacham 123-127)

With the possible fire scenarios identified, it is then necessary to narrow these down into a manageable number of design fire scenarios. There are two general methods for determining design fire scenarios. The first is the probabilistic approach. This method uses statistics to determine the likelihood of a fire occurring and the likely outcome of the fire. This allows fire scenarios which are either very unlikely or have an acceptable outcome to be eliminated. The other approach is the deterministic one. This method uses analytical models to determine whether a fire scenario will exceed the performance criteria. Using this method, enough design fire scenarios are selected to provide a sufficient representation of all possible fire scenarios (Ramsay et al. 2.3-2; SFPE 47-51).

With the design fire scenarios identified, a design fire curve is determined. Without going into too much detail on the fire engineering involved, a design fire curve is a representation of the development of fire over time. This development is characterized by ignition of the fire, then growth up to the flashover point after which the fire burns at a steady state until decay. The design fire scenarios are then used to evaluate possible designs. This involves determining for each of the design fire scenarios whether a design will meet the performance criteria. From the designs that meet the criteria, the final design is chosen (Custer and Meacham 47-63; SFPE 57-65)

10.2.3 Advantages of Performance-based Design

There are several important advantages Performance-based codes have over prescriptive codes. One such advantage at the heart of PBD is the establishment of a clear design goal. A well-defined objective provides the designers with a better understanding of what the design needs to accomplish. This allows them to more easily determine an alternative to the solution detailed in the code. PBDs are also able to more easily incorporate the latest advances in technology and, of particular interest for this project, fire engineering. Prescriptive codes have to be edited and updated at a fervent pace in order to be able to incorporate the latest materials and methods. Prescriptive codes do allow the use of new technology if it can be shown to be as safe

as proven technology, but the details of this process are not as clear with prescriptive codes as it is with Performance-based codes (Barnett). Because Performance-based codes allow designers to determine the best method of achieving the provided goal, they can put new technologies into practice without excessive alterations to the code itself (National Fire Protection Association 8-10; About the Building Code).

PBD also allows the building to employ a comprehensive fire protection system. Because the code leaves the method used to satisfy the objective up to the designer, the fire systems can be made to work together to achieve that goal as opposed to each having to meet individual prescriptive requirements. This allows for more efficient design and can lead to safer buildings when the fire engineering systems work properly. This efficiency can also allow the same or greater level of safety to be achieved while still decreasing the costs. When the fire safety systems are designed as one entity to meet certain objectives, this allows the designers to eliminate redundancies and therefore save money (Custer and Meacham 19).

10.2.4 Disadvantages of Performance-based Design

The disadvantages of PBD are primarily associated with the design fire scenarios. As described previously, the creation of fire scenarios requires the engineer to consider many characteristics of the building and its occupants. Often it is necessary for the engineer to make assumptions about these characteristics as well as other inputs in the fire model. These assumptions have inherent uncertainties that can affect the validity of the design fire. Communication between stakeholders can affect the reliability of the design. It is important for the occupants of the building to have an understanding of the assumptions made about the use of the building. It is equally important for the designers to understand the occupants' needs and make accurate assumptions based on these needs. Otherwise, an inadvertent change can drastically alter the performance of the building. A good example of this might be propping open fire doors. This is something that can easily be done out of convenience without any consideration of fire safety. This can have a serious impact on compartmentalization, allowing smoke and flame to spread more quickly through a building. Conflicts of interest between pleasing the client by decreasing costs and ensuring the building is safe can also affect the quality of the fire protection systems.

Finally, enforcement of PBD can be an issue due to the subjective nature of the codes. The specific requirements will be different for each building and will often require thorough analysis by individuals with more training than the typical building certifier. These disadvantages will be discussed further throughout this section.

10.2.4.1 Uncertainties in Performance Based Design

The engineering aspect of PBD can often be better defined by using more accurate assumptions. The design of the building should ensure the safety and protection of the building's occupants. The only way the engineers can make better assumptions is through feedback from the occupants of the building. This way the engineer can see if there are problems occurring with his assumptions and if there are problems, the engineer can fix them to provide better assumptions.

Meacham uses the term "acceptable risk" to provide a skeptical term that must be evaluated ("Assessment" 27). It is important that firefighters can get into the building, get the occupants out of the building and safely get out of the building as well. PBDs have to accommodate for all aspects of fire safety and this should include all people. The engineering of Performance-based fire protection is also to "predict the outcome of possible situations and also use different tools to evaluate these situations" ("Assessment" 28). The engineers can then scientifically determine solutions and ways to change the designs to work properly. If the PBDs are working to their predicted performance or better, then the engineers can ensure people will be safe.

The human aspect is a more difficult topic to evaluate than others. People are spontaneous and hard to predict which makes it very difficult for the engineers to predict how they will react or respond to a fire. In some cases people may not respond to a fire alarm initially or just may not even hear it. In this case, Meacham shows how people are not always quick to respond to a fire. The FSEs sometimes assume occupants move to an exit immediately when they hear a fire alarm, but:

In current performance-based fire protection designs, the time assigned by an engineer to the time interval required for people to begin

evacuation can be zero (people are assumed to begin travel once the alarm sounds), point values as low as 20 or 25 seconds, or a multiplicative factor of the estimated travel time. (“Assessment”, 30)

This may not always be true, particularly if someone is hearing impaired or otherwise prevented from being able to quickly identify an alarm.

10.2.4.2 Risk Communication

It is important in PBD for the final occupants of the building to understand what they need to do to prevent fire as well as what they need to do in the event of a fire. Without this knowledge, fire can render even the best fire safety solution ineffective. This is particularly true of the assumptions made during the fire analysis, which human behavior can often invalidate. It is important for the FSE to make clear how to maintain the assumptions but this is not always done. An example of this is the Luxor Hotel in Las Vegas. In the fire analysis, the engineer assumed the size of the fire would be limited to a certain heat release rate primarily based on the assumption that most of the decorations and furnishings on the unsprinklered casino floor would be non-combustible (Brannigan and Smidts 415). The documentation did not specify, however, any enforcement mechanism for this assumption. This risk communication issue is illustrated further by an MFB study which found most fire victims were unprepared to deal with the fire and did not feel confident during the ordeal (Metropolitan Fire and Emergency Services Board 21).

10.2.4.3 Sensitivity of Fire Models to Variation in Inputs

Despite the sophistication of the fire models in use today, they still require the engineer to determine and input the values of variables used in the model. Because there is always going to be uncertainty in these values it is impossible to be certain the outcome predicted by the model will match reality. There are methods to combat this uncertainty, which include factors of safety based off sensitivity analysis performed by the engineer during the design process. Sensitivity analysis is a method of determining how changes in model parameters affect the results generated by the

model (Peacock et al. 110). Using this, an engineer can determine a factor of safety that accounts for the uncertainty in the inputs.

Experience, or lack thereof, of the engineer using a computer model can affect the accuracy of a design fire utilizing its results. The use of a computer fire model requires the engineer to have an understanding of the model used by the computer and proper modeling techniques. This understanding comes with training and experience, something which many fire safety engineers may not have. Key Performance Indicators (KPI) can be used to aid in the modeling process. KPIs are quantifiable measurements of critical success factors defined by an organization. Using these one can determine how well a model is being used. This provides the engineer with guidance and allows the engineer to have a better understanding of how to appropriately use the computer model. Although KPIs are very useful, they require extra time, money and training in order to define and use properly (Kuhn et al. 4-7).

This analysis works well for variables such as material properties and initial conditions such as temperature and pressure. Human behavior however, is much more difficult to quantify and plays a major role in the fire scenarios. Data on human behavior is limited and is complicated by the changing nature of human behavior over time. Simple things such as tenant modifications, renovations, maintenance and repair can have a significant impact on the amount of fuel and increase the severity of a fire (Bukowski). This uncertainty affects the overall reliability of the design in several ways. First is the accuracy of the design fire scenario. Many assumptions are made about the actions of the occupants both before and during a fire and these have a large impact on the outcome of the fire scenario. Human behavior also makes it difficult to guarantee the conditions used in the design fire scenario, which were relevant at the time the building was constructed, will stay the same. It is very difficult to use past data to predict the future with regards to human behavior in the same way this is done with events which occur more regularly over long periods of time, such as hurricanes or earthquakes. This makes planning for the future in the design extremely difficult. These uncertainties mean the actual safety level of buildings in use might not be the same as the safety level predicted by the design and could fall below the performance requirements specified by the codes (Brannigan and Smidts 344-345).

10.3 Melbourne Implementation

Because this project centers on the implementation of PBD in Melbourne, it is necessary to discuss some of the elements specific to Melbourne. The role of the MFB and the legislative structure and regulations that allow the MFB to influence the building process is an important aspect of studying Melbourne's implementation of PBD.

The powers afforded to statutory bodies such as the Metropolitan Fire Brigade derive from a series of legislation passed at the state level. The BCA is adopted as the standard for use in Victoria in the Building Regulations statutes. The Building Regulations 2006, adopted by the legislature of Victoria, detail how the building code is applied, both during the construction of the building and after, as well as the powers of all of the various agencies. All of the technical details of the building code implementation are deferred to the BCA (Edwards; Building Regulations 2006).

During construction, the MFB has authority over certain sections of the design of a building when it requires an engineering analysis due to PBD. These sections limit MFB powers to a list of specific fire safety appliances (Barnett; Edwards). The areas where the MFB chief officer has authority, from the Building Regulations 2006, Section 309, are:

- (a) fire hydrants;
- (b) fire hose reels;
- (c) fire control centers or fire control rooms;
- (d) fire precautions during construction;
- (e) fire mains;
- (f) control valves;
- (g) booster assemblies;
- (h) emergency vehicle access;
- (i) fire indicator panels;
- (j) proscenium curtain drencher systems;
- (k) fire services controls in passenger lift cars.

The chief officer of the MFB must approve any variations from BCA Deemed-to-Satisfy provisions concerning the systems listed in the building regulations, although this decision may be appealed before the Building Appeals Board (Edwards; Building Regulations 2006).

While MFB does have some authority for buildings using PBD, they do not have enforcement power outside of this area. The person with legal authority to certify a building's safety is not actually the MFB or a team of engineers; it is the building surveyor³. The building surveyor is sometimes connected to the city council, but in most cases is actually from private industry. The surveyor assembles all of the documents for a building, and must deliver any PBD reports to the town council. A building inspector must have a graduate certificate on PBD in order to evaluate the fire engineered portions of the design, but is not likely a fully trained engineer (Edwards; Barnett; Building Regulations 2006).

MFB is involved in the PBD process in either of two situations: when a building is designed with Performance-based alternative design, or when the designers of the building request that the MFB examine the PBD document. During the design of a building, MFB has the power to make "recommendations" about the design, and these recommendations are legally binding on the designer and builder. MFB can also make "comments" concerning less important issues or issues outside their jurisdiction, but the designers are not legally obliged to act on them (Metropolitan Fire Brigade).

After the building has been constructed, MFB lacks significant power to force changes in the event a building no longer meets code specifications properly. Due to some political difficulties, some of the MFB's powers to inspect buildings were legislated away. Currently, MFB has the power to call for an inspection of a building's fire appliances (hose reels, sprinklers, etc). They cannot call for an inspection or shut down a building to deal with other issues affecting fire safety, such as drastically changed fuel loads. (Barnett).

³ In all cases in this paper *building surveyor* can be used interchangeably with *building certifier*, although *building surveyor* is the term used in Victorian regulations.

The primary regulatory body after the construction of a building is the Municipal Building Surveyor (MBS). The MBS is employed by the city council and is responsible for ensuring the safety of people within buildings in Melbourne. Towards this end, the MBS has the power to inspect buildings and force changes be made. Ultimately, the MBS can prosecute those who fail to satisfy the regulation but this power is rarely used, instead the focus is on negotiation⁴. Another regulatory body, primarily responsible for construction sites, is WorkSafe. This is a government agency responsible for occupational health and safety. WorkSafe has the power to inspect work sites and penalize those who do not meet the regulations. Additionally, WorkSafe engages in activities to educate workers and their employers.

10.4 Other Building Code Implementations

In order to find ways to improve the Melbourne implementation of PBD, looking at implementations used in other areas can be useful. In these sections, the variations from the policies used in Melbourne are covered, as well as the enforcement powers afforded by the different building regulations.

10.4.1 Queensland

The code for Queensland derives from the BCA, as all the building codes in Australia do, with small implementation changes. The Queensland Fire and Rescue Service (QFRS) functions as an agency that reviews Performance-based alternative designs for compliance with building regulations, but the building certifier is the person wielding the power to sign off on the building's safety. The building certifier performs essentially the same role as the building surveyor in Victoria. Some other points of interest in the Queensland code implementation are the inclusion of arson in the list of fire scenarios to evaluate, the possibility of having a building storing dangerous materials built using PBD, and the forceful recommendation to use sprinkler systems (Queensland Fire and Rescue Service).

⁴ This information comes from interviews with the MBSs in Melbourne, and more detail can be found in Appendix D.4, which covers the relevant interview. Details on the citations of interviews for the purposes of this paper can be found in Section 12, and Section 12.2.1.

10.4.2 Australian Capital Territories

The code for the Australian Capital Territory (ACT) derives from BCA requirements, but there are several elements of interest to this project. The ACT Fire Brigade (ACTFB) uses the Performance-based framework established by the BCA, but does detail some exceptions, such as falling back to prescriptive codes for buildings containing dangerous chemicals or explosives. There are other clarifications to the requirements and recommendations of the BCA, such as recommending the use of sprinkler systems, or that designs not rely on fire brigade intervention to ease performance requirements. There are also some interesting requirements as to the relation between the FSEs, the designers, and the occupants of the building. The fire engineering report, created during the design and evaluation of a PBD solution, needs to be “delivered [to] and understood” (Australia Capital Territory Fire Brigade) by the owners, occupiers and maintenance staff of the building. The regulations require building management and maintenance follow the requirements of the fire engineering report throughout the life of the building (Australia Capital Territory Fire Brigade). This is an important aspect of how the ACT building regulations work, as the documentation transfer from the FSEs to the occupants is required to occur, but this does not necessarily mean the owners actually *understand* the documents.

10.4.3 Australian Department of Defense

The Australian Department of Defense has its own set of building regulations which are used by all of the armed forces in Australia. These building regulations reference the BCA, but only as a minimum set of requirements which are supplemented by far more strict regulations specified in the Manual of Fire Protection Engineering (MFPE) distributed by the Department of Defense. These strict regulations are the primary difference between the military’s regulations and civilian building regulations. This is due to both the extra protection required for the military’s critical assets as well as the extra resources the military is able to bring to bear on the issue of fire safety. There are several regulations which are of interest in relation to this project. One is the post-construction mandatory maintenance and inspection schedule the regulations specify to ensure fire safety systems continue to function throughout the life of the building. Another interesting feature of the MFPE

is specific to PBD, which requires the display of a sign similar to Figure 10-3 in the building. This sign lets the occupants know the building's fire safety system relies on certain assumptions which must be maintained (Australian Government Department of Defense).

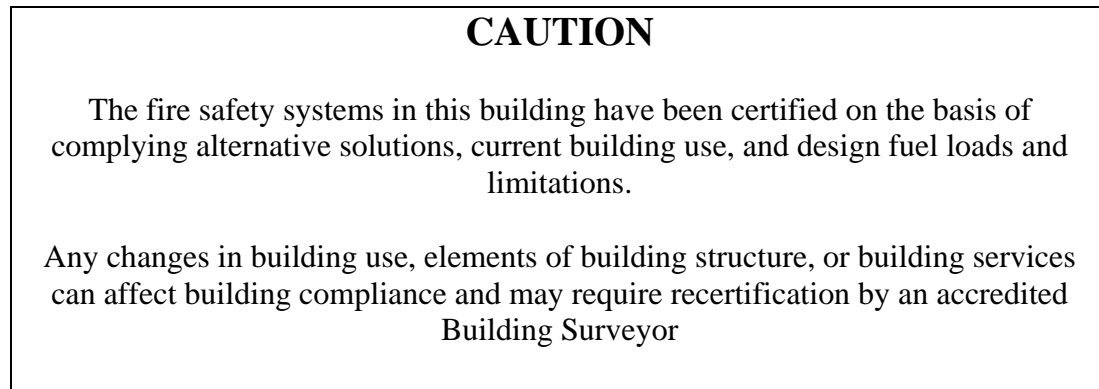


Figure 10-3: MFPE Alternative Solution Signage

10.4.4 Massachusetts

In the Commonwealth of Massachusetts in the US, the building codes are not based on PBD, but rather on prescriptive codes. While the codes themselves may differ significantly, there are some elements of the way the codes are enforced relevant for comparison. In Boston, Massachusetts, the fire department has the right to enter any premise for the purposes of inspection to determine if a “material or condition” (“Boston Fire Prevention Code”) exists that could lead to a fire or explosion, or be dangerous in the case of a fire. The inspector also has the ability to order a problem fixed, either by the owner or by the fire department at the owner’s expense (“Boston Fire Prevention Code”). This is significantly different from the enforcement abilities the MFB has in Melbourne.

10.4.5 UK

Great Britain was one of the first nations to develop a Performance-based building code. The primary motivation for this change was that the prescriptive building codes had grown too cumbersome from hundreds of years of modifications and additions. In 1985, the building code, titled Building Regulations, was revised to utilize Performance-based design which reduced the document from 307 pages to 23 (The Evolution of Performance-Based Codes 12). The new building code contained

very few details on alternate designs and approval methods, making many engineers reluctant to try new methods. Additionally, the reluctance of insurance companies to insure buildings not designed to meet the old prescriptive codes made it difficult to encourage the use of PBD. In 1991, the Building Regulations were revised again to include some of these details and a code of practice was developed to govern fire safety engineering practices in building design in an effort to encourage the use of alternative methods (Barnett; International Activities 56; The Evolution of Performance-Based Codes 12-17).

10.4.6 New Zealand

New Zealand started developing Performance-based codes in the early 1990s. FSEs of New Zealand developed a five level pyramid model, listed from the top down: Objectives; Functional Requirements; Performance Criteria; Verification Methods; and Examples of Acceptable Solutions. This pyramidal structure of the building code standard is very similar to the BCA code pyramid used in Australia (Babrauskas).

In 1992 New Zealand had some Performance-based solutions, but they used the prescriptive requirements as “acceptable solutions” and rewrote the prescriptive requirements so they would meet the performance objectives. New Zealand also made the controversial decision that “the protection of property at the regulated occupancy is not a matter for the code but is rather between the owner and his insurance company” (Bukowski 25-27). The code now only includes the provisions to protect the third parties, meaning the insurance companies. The property that belongs to the third party is protected. This gives more work to the insurance companies because they must now develop and enforce their own regulations, in addition to the regulations stated in the code (Bukowski 25-27; Barnett).

10.5 Background Summary

The background research on this project is especially important due to the technical nature of many of its aspects. This literature review covers the background behind PBD, many of the details of its implementation, and several areas for

examination concerning design considerations and important details in practice. In order to put this information in context, this section covered prescriptive design, as well as the general building process. The main findings of the research were while the Performance-based codes are relatively simple in their statement; there are many subtle areas that need to be understood in order to implement them properly. In every aspect of the use of PBD, there exist tradeoffs between safety and feasibility and cost, as a number of other constraints to optimize in the construction of a building.

11 Methodology

In order to evaluate the implementation of Performance-based Design (PBD) in Melbourne, there were two primary research objectives: looking for the existence of changes in a building's usage that affect the validity of the fire safety solution's underlying assumptions, and determining the level of awareness among building owners and managers of how and where these changes can occur. The primary research technique to address these objectives was a series of case studies on buildings throughout Melbourne. In each of these case studies, the building was visited to look for any discrepancies from its usage as assumed by the fire safety solution, which fulfilled the first research objective. The second objective, determining the level of awareness of building owners and managers of fire safety specifications relied on a series of interviews of the people involved. In order to gain a wider breadth of experience on the implementation of PBD, interviews of private Fire Safety Engineers (FSEs), fire services personnel and building surveyors were crucial to be able to generalize conclusions.

11.1 Research Objectives

These objectives concerned how the way in which people sometimes live in or use a building can conflict with assumptions made in fire safety solutions. The understanding that the fire safety solution does not change is a key aspect of these objectives. Once the fire safety solution is created for a specific building, it remains constant as the basis for the design of the fire safety systems. The only changes that occur are the ways in which people use the building. Some changes may cause conflicts with the fire safety solution assumptions, which can result in a lower level of safety in the building. The building owners and managers may not know the effects of these changes. This project identified some situations where these discrepancies are occurring and how knowledgeable building owners and managers are of the effects of these discrepancies. Using this information, recommendations were made to improve the implementation of PBD in Melbourne.

11.1.1 Existence of Subtle Usage Changes that Undermine the Design Fire

The design fire is something that will not change throughout the lifetime of the building. When the engineer designs the building, the design of the fire safety systems is based on the impact of the design fire. The engineer makes assumptions about the building occupants and the use of the building. The assumptions that the engineer made may not match the way the building is used. Sometimes changes to the building occur that the engineers did not expect. The people that use and maintain the building can undermine the fire safety solution by making changes, even small ones, to the building. For example, the people living in a building may change the use of a room, which could be as simple as adding or just rearranging fuel in the room, completely transforming the needs for fire safety in the room and changing the performance of that original design. Prior to the completion of this research project, the existence and extent of these potentially life-threatening changes was unknown. The visits to the buildings in the case studies identified many of these issues.

11.1.2 Knowledge of Subtle Usage Changes that Undermine the Design Fire

The second research objective was to determine whether those who run the building are aware of how the building could be made unsafe by changing its use. The knowledge of the effects of these changes is important for the safety of people in and around the building. If the impact of these changes can be communicated from the designers to the managers and owners, then the managers and owners will be less likely to accidentally make a change that results in unsafe conditions. The existence of trends of similar issues throughout multiple buildings indicated that there might be some miscommunication occurring during design, which results in the assumptions not reflecting the actual use of the building. The team conducted a series of interviews of building managers and owners, as well as others involved in the building process; to determine the level of knowledge they have of the policies necessary for the building to remain safe.

11.1.3 Onsite Scheduling

Organizing the case studies and the interviews were the main limiting factors in scheduling for the project, as both involved coordination with several other parties. The schedule for the project is shown in Table 11-1. During early phases of the project, much of the time was spent completing research as well as reviewing the design documentation for each of the case study buildings. This early phase was important, as the areas targeted during the visits and the building-specific interview questions were dependent on key design features identified from this documentation. After this review was completed, the building visits were carried out. The actual process of visiting a building was relatively short; allowing the team to complete the actual visit quickly provided the necessary MFB personnel were available. The initial target for the number of case studies was 10 different buildings. However, the size of the sample that the team actually visited and analyzed was 6 buildings, 3 residential and 3 commercial. After the information was collected from both building-specific interviews and building visits, it was analyzed to determine if any general patterns existed.

Also during this time, individuals were contacted to arrange in-person and other types of interviews, which were important to gain more depth to the information gathered.

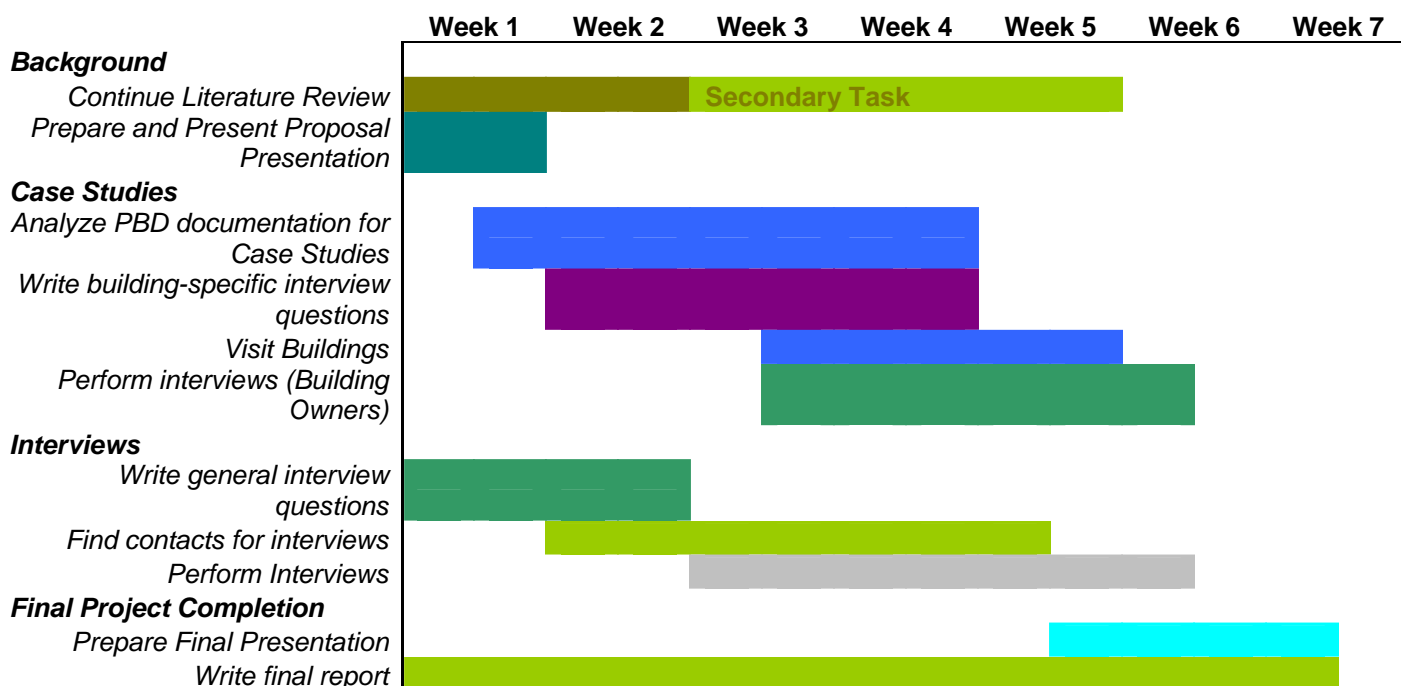


Table 11-1: Project Gantt Chart

11.2 Case Studies

The primary means of accomplishing the research objectives was to perform case studies of individual buildings designed using Performance-based methods. These buildings were selected by Professor Barnett and the MFB at the start of the project. Each building was visited by the team along with an inspector, or two, from the MFB to identify discrepancies between the current use of the building and the assumptions made in the design specifications outlined in the PBD documentation. Building owners, managers and maintenance staff were also interviewed to determine their knowledge of the assumptions made in the design of the building and how those assumptions can affect fire safety in the building.

Prior to the visits it was necessary to identify the key performance criteria for each individual building. In order to accomplish this, the design documentation was examined for each building. Because of the nature of PBD, the fire safety requirements vary from building to building. For each building, it was important to determine what the important elements of the building's fire safety system were. This included features such as fire doors, which automatically close to help contain a fire,

fire detection systems, or sprinkler systems. It was also important to determine the performance requirements for each of these systems. This information gave direction to the visits. The team also established what assumptions the designers made. This includes assumptions on the usage of the building, assumptions about the occupants such as their mobility or responsiveness, and the quantity and arrangement of fuel in the building. Identifying the important assumptions was necessary to determine the specific information needed from the building owners and managers.

The fire engineering reports, and the surrounding documentation, also provided a view of how the actual process of the fire engineering review works. Because the documentation on record at the MFB also included a chronological history of all reports, applications and correspondence during the approval process, it was possible to see how a building had changed during the course of its design, and the approach taken by fire services, the original FSE, and the developers. This was useful in seeing how communication took place, and gave an indicator as to what factors influenced the design. Also of interest in determining the usage requirements of a building was the occupancy permit, which is a much shorter document that is more visible to the owners and managers than the fire engineering report.

A visit was performed for each building selected for the project. The visits were performed with the assistance of inspectors and engineers from the MFB. The building visits themselves were relatively short, as it was only necessary to verify the areas of concern of the PBD solution identified during the review of the documentation. One important aspect of performing the site visits was to ensure that the building managers did not have prior notice about the visit. This was to ensure that any problems would not be fixed just before the visit, as these site visits need to be a snapshot of normal use, not changed to be better for the inspectors. The focus of the visits was on the critical design features identified from the PBD documentation. It was necessary to determine whether these building features in their current form were compliant with the performance criteria established in the design. The primary areas of concern were issues arising from either a change in building usage which resulted in the fire safety systems being less effective or from improper maintenance which led to an ineffective system. The most important issues were those that

rendered the fire safety solution ineffective. This provided the information needed to determine whether fire safety solution assumptions were valid at the time of the visit.

The team also interviewed key building personnel such as owners, managers, and maintenance staff. The primary purpose of these interviews was to determine how aware owners, managers, and maintenance staff were of the PBD requirements for the building and what policies were in place to satisfy these requirements. Information on these policies not only provides a more detailed picture of the building at the time of the visit, it also gives some insight on the potential for future problems. If few discrepancies were found, the presence of these policies helped to indicate whether this was due to mere coincidence or actually a product of good management. The information from the interviews was also compared to the observations compiled during the visit to determine whether effective communication of fire safety information was occurring. The details of these interviews will be discussed in the next section.

11.3 Interviews

Interviews were an important facet of the research for this project because the team needed to look at more than just the state of the buildings examined in the case studies to determine how well PBD was implemented in Melbourne; it was necessary to understand the practical details of the implementation to be able to address the problem. Talking to the people involved in the building process allowed a broader view of the use of buildings than what the short visits allowed.

The in-person and phone interviews were semi-structured and, with the subject's permission, recorded to ease the analysis and compilation of results. The goal with the interviews, especially with the fire safety professionals, was to provoke more discussion and elaboration on experiences with PBD in buildings. The number of building owners and managers interviewed was dependent on how many buildings were visited, although as many interviews with fire safety professionals were performed as possible.

In order to get a more complete picture of the implementation of PBD, a variety of professionals involved in the building process were targeted, including private FSEs, building surveyors, and engineers and inspectors working with fire services. Because these people were scattered across Australia, they were primarily subjects for telephone interviews. These telephone interviews focused on essentially the same set of topics used for the face-to-face interviews, but were designed to add more structure to the questions in order to make these interviews quicker to complete and results easier to collect and analyze. The interview questions for each targeted group comprise Appendix B. More questions were asked as the interview was performed due to some other issues that were brought up by the interviewee or past interviewees.

The selection of general interview subjects occurred by several means. Initially, the team started with a series of contacts, particularly fire services personnel around Australia and building surveyors, supplied by the staff at the MFB. The team also used publicly available lists of registered professional building practitioners available through the Victorian Building Commission. This list, primarily targeting private FSEs, included approximately 70 engineers, and the team contacted 18 of these FSEs through a random selection process. Initial contact for these interview subjects started with formal emails, consisting of a brief description of the project and a request for an interview. Of the FSEs selected, nine either did not respond or were unable to help. In the other subject categories, initial subjects from MFB-supplied contact information were able to provide additional possible contacts, which were added to the list and contacted during the course of the project.

An important aspect of the design of these questions was the relationship between each of these groups. By asking multiple groups how communication works between each (such as asking FSEs and building managers how fire safety information passes between them) it was possible to determine where lapses in communication lie. It also allowed the team to determine whether any missed information was due to certain groups never being informed (i.e., engineer never informed of certain usage requirements) or the information was not understood (i.e., a building manager did not understand what policies need to be in place despite being

told). When combined with the information from the case studies on the actual implementation of the PBD solutions, this made it possible to determine where communication issues caused implementation issues.

11.3.1 Private Fire Safety Engineers

Private FSEs play a significant role in the design of PBD solutions, and were a major target group for interviews. Because of their role in the design process, there were several areas where they had useful perspective: getting details on the build process, finding constraints and factors that influence design, learning how fire safety knowledge passes from the engineers to business owners, and general experience with PBD. These goals stemmed from the roles that FSEs play in the use of PBD, as not only are they experts in PBD, they also are among the parties that are actively involved in its implementation. The specific questions and topics discussed are outlined in Appendix B.

The most basic of the areas discussed was the general building process involved with PBD, including the details of who is involved and what issues arise during the process. The constraints that influence design choices such as cost, speed of construction, maintenance difficulty or politics were of particular interest because these could be reflected in the existence of small deviations from the performance specifications. This information allowed the team to target and prioritize areas for investigation more accurately. To make sure these details fit in with the broader understanding of PBD, finding general observations of PBD, such as advantages, disadvantages and consequences was also useful. While some of this information was found in background literature, the less obvious details gleaned from experience were useful in looking for subtle discrepancies in buildings' use and construction.

There were several communication mechanisms examined, specifically the passing of fire safety information from FSEs to building managers, passing more detailed fire analyses to fire services and building surveyors for review, and receiving usage information from the owners of the building. For each of these avenues of communication, there were questions that targeted not only how information passes from group to group, but what levels of feedback exist to determine how much the

other group is aware of. In particular, it was useful to understand how the engineers worked to inform the building managers and owners of the important assumptions underlying the design. This avenue of communication can be verified for its effectiveness by comparing what the building managers and owners actually know to what the FSEs thought they should know. This aspect of communication is particularly important, as non-technical building managers and owners will not be able to understand the complete fire analysis, and will need this information distilled into implementable policies. This particularly large transformation of the fire safety information makes it a likely location for communication breakdown.

There were a few possible concerns in interviewing FSEs for information on PBD implementations. While they were experienced in PBD, it was important to retain some degree of objectivity when approaching the building case studies by not simply looking for what PBD implementation problems the engineers perceived. While this project may not have been statistically significant because of the small sample sizes of buildings, it was important to avoid approaching the case studies with any biases that might have resulted in missing important details.

11.3.2 Building Owners, Managers and Maintenance Personnel

One of the primary research objectives for this project was to determine the level of fire safety knowledge among those who own, maintain and occupy buildings, so an obvious source of information was to ask these people questions to determine their familiarity with the fire safety systems of their building. Because this was a major area of research for this project, these interviews were a priority; however the exact execution of them varied greatly depending on the circumstances of the case study itself.

While these were important interviews, they were among the more difficult ones to conduct because of the delicacy of the situation in which the case studies were performed. There was an important balance to manage between getting unfiltered information for the interviews while ensuring that subjects did not feel alienated or tested. It was also important to avoid questions that might lead the subject to a direct answer, focusing instead on questions that would provoke the subject to giving a more

comprehensive response. An example of this shift might be asking “Are there people here all the time? Even at night?” to find out what minimum staffing levels are, rather than asking “What is your minimum staffing number?” These indirect questions relied on the manager’s urge to impress the team with safety standards, but also necessitated follow-up questions to target the areas of interest from the PBD documentation.

The issue of gaining the cooperation of building managers was made even more difficult by unannounced visits, which could have made some building managers more defensive. The solution was to maintain a level of tact in approaching questions, and avoid being judgmental of the subjects’ responses during the interviews. The fact that the team performing the interviews is not comprised of FSE students was an advantage, as building managers might feel that team was in less of a position to judge their policies and knowledge than a professional FSE or inspector.

The questions listed in Appendix B, outline a template for these interviews. Additional questions, specific to each case study, were necessary based on key areas of the PBD documentation. These questions focused on several key areas. Questions were asked concerning the amount of knowledge the building staff had of the assumptions made during the design process and the implications of invalidating these assumptions. Questions about the design process and the amount of communication that occurs among various stakeholders were also asked. Finally, the team attempted to determine the amount of concern which existed among the owners and managers about fire safety issues. In addition to the previous information, the team gathered information about the maintenance programs in place for the fire safety systems. The information obtained from these interviews provided a clearer understanding of the amount of communication that existed between the building owners and the design team.

11.3.3 Building Surveyors

Another important group of interview subjects was the local building surveyors. Because of the degree of regulatory power wielded by surveyors, they provided an important perspective on the implementation of the building codes in

Melbourne. The target information concerned mostly the role of the Building Surveyor and level of understanding of PBD that building surveyors have. The specific aspect to this project is whether the Building Surveyor has a sufficient understanding of PBD to make informed decisions when issuing permits. Because of the role surveyors perform in the process, they also have several avenues of communication with other parties involved, so determining the effectiveness of their communication with private FSEs, building owners, and fire services personnel was important. Building surveyors were also likely to have experience with a variety of buildings, so asking about past experiences was an important aspect of the interviews.

Because understanding the ability to make informed decisions was a central goal of interviewing surveyors, some level of tact was necessary to avoid asking “Are you competent to make informed decisions when issuing permits?” The questioning approach taken was to rather ask about how effective the fire engineering reports were; highlighting important aspects of the design. This method both targeted quality of communication and gave an indirect idea of the level of understanding of PBD that surveyors have. The other method of learning about the knowledge of surveyors was to ask about their education and certifications, specifically focusing on what courses were taken and the depth to which fire safety was covered.

11.3.4 Fire Services Personnel

The last major interview group was the people involved in the review and enforcement of PBD within the fire services. This consisted primarily of FSEs, who review the fire engineering reports, and inspectors, who examine the implemented design after construction. The interviews targeted the level of involvement the fire services have after the initial design review that occurs prior to construction. Particularly, the team focused on the time period after the building has been completed and occupancy has started. As with all the interview groups, descriptions of any experiences or observations concerning the practical implementation of PBD were very useful in understanding the issue.

The questions targeting those who review fire engineering reports for regulatory approval primarily looked at how communication between the reviewing FSEs and the building stakeholders functions. One of the main goals of these questions was to see where effective design feedback occurred, and how it was implemented. Some of the questions examined at what point the fire engineering report came to the reviewing FSEs, how reviewing FSEs check the usage assumptions made in the fire engineering report, and how recommendations and comments made on a design are implemented in the final design.

The questions targeting those who inspect buildings primarily examined the enforcement powers to force code compliance if usage changes render a building's PBD solutions ineffective. This was important for the project because feedback on the maintenance of a design is necessary to ensure that the PBD solution remains effective during occupancy.

11.4 Analysis

As case studies and interviews were completed, the group analyzed the information gathered looking for general patterns sufficient to warrant recommendations. The generalizations made were not necessarily sound enough to show strong conclusions by themselves, but rather, the common areas of concern can function as a pilot study to direct future long-term analysis.

12 Findings

Due to the size of the project, both in the complexity of the interactions between parties and the technical aspects involved, these results and analyses are arranged to present as much of the information as possible. It should be noted in the following sections that the data gathered in this project cannot be analyzed in a statistical manner due to the research methods used and the small sample sizes. In lieu of statistical trends, the findings are stated in the form of common observations from the interviews and case studies. Examples and specific experiences from interviewees are also used as support for these findings. Buildings used in case studies reference the building identifiers used in Appendix C, and cited by letters. Interviews are cited by subject number in Appendix D, and will be cited as Subject 1, Subject 2, and so forth.

The information targeted by the research objectives is most directly measured by the case studies, as examining specific buildings allowed the team to verify specific requirements specified in the original designs. Section 12.1: Case Studies, focuses on presenting the information on common areas of concern found in the buildings examined in the case studies. This is because some of the specific issues found in buildings may be useful in future studies of Performance-based Design. This section also provides the answer to the first research objective of determining whether small usage changes exist in fire-engineered buildings that defeat the fire safety systems.

Section 12.2: Owners and Manager Implementations, addresses the second objective by examining the management approaches taken to usage changes and awareness of fire engineering requirements. This section uses a mix of results from case studies and interview subjects' experience to determine the level of knowledge and awareness among building managers. Because the management policies and implementation are a result of a complex series of interactions between developers, owners, fire engineers, building surveyors and fire services, this section also includes information on the many influences that affect management policies and their implementation.

Because a major topic of this project is to examine the communication between the various parties involved in the building process, Section 13.3: Communication, concerns the means by which communication occurs. The specific focus is on the mechanisms that allow for the detection and resolution of unsafe usage changes. These communication processes are important to examine in order to ensure practical communication methods, implementable with existing resources, are able to address the problem. Also of interest in examining the communication during the lifetime of the building is to look at the actual means by which communication occurs, particularly the documents that pass information between parties, such as the fire engineering report and the occupancy permit.

12.1 Case Studies

Case studies were performed on six buildings located in Melbourne. These buildings had all been built using alternative solutions, most of which made assumptions about the use of the building and management policies which needed to be maintained, and were in some form of occupancy during the time of the site visit. Appendix C details these alternative solutions and the required policies as well as the results of the site visits for each of these. To protect the confidentiality of those associated with these buildings, their names and addresses have been omitted. Three of the case study buildings were residential and, while the sample size is small, they covered a wide spectrum of compliance. Three commercial buildings were visited, with a focus on storage warehouses that deleted sprinkler systems as a part of their designs as well. For each visit the team prepared a list of requirements for the fire safety solution to function as designed. These lists were based on the design documentation for the individual buildings. During the site visits, team determined the level of compliance with these requirements. When possible, the manager of the building accompanied the team on its visit to answer questions. This was the case for Buildings A, D, E and F. The official visit with an MFB inspector to Building C was lead by the building manager, although the majority of observations made did not occur in the presence of the manager. In Building B, a later interview was used to obtain more information.

The buildings were selected by MFB engineers as likely candidates for site visits, based largely on their previous experience during the review process. Building C was added to this initial residential list, as it provided a convenient long-term case study because it was the team's place of residence. All three of the commercial buildings were selected from the pool of available buildings and were found to be complete and in use for several years since construction.

Of the residential buildings, Buildings A and B were each subjected to one site visit, giving the team a snapshot of the conditions in each building. Building C, however, was observed continuously over the course of the team's stay in Melbourne. The commercial buildings, Buildings D, E, and F, were each subjected to one site visit, each accompanied by a building manager. There was a seventh building, Building G, which was not visited as it was discovered that the building had not been completed at the time of project.

Each site visit included at least one MFB inspector, who also looked for issues concerning essential safety measures that were not necessarily part of the lists prepared from the fire engineering reports. In cases where significant safety violations existed, notices were issued to the building owner. These notices give a certain period of time, usually either 30 or 60 days, to the owner to have a problem fixed, after which there would be another inspection. The issuing of these notices was handled entirely by the accompanying inspector.

12.1.1 Residential Buildings

The buildings in the pool of residential buildings were relatively similar in their use and other constraints. The buildings (A, B and C) were all apartment buildings built a relatively short time before the site visit. Two of the buildings, A and B were approximately three years old, while building C was still under construction with staged occupancy that had been occurring over the previous several months. Each was primarily used as apartments (Class 2), although most had other areas such as car parks and retail space. The buildings ranged from 9 to 36 stories in height. All were tall enough for the DtS codes to require an automatic sprinkler

system. Two of the buildings (A and C) were connected with other buildings as a part of a complex, but were examined as individual buildings for the purposes of this study. Building B was a stand-alone building. Common deviations from DtS included the use of a single egress stair (B and C), reduced Fire Resistance Levels (FRLs), and extended egress travel distances. While it is clear that the buildings were in many ways similar, the actual level of adherence to fire engineering requirements varied greatly, showing a spectrum of compliance with an excellent building (A), a mediocre building (B), and a potentially disastrous building (C).

During the site visits, the team looked for evidence to determine the level of compliance with fire engineering requirements. Whenever possible, a manager escorted the team during the visit to answer questions. This was the case for Building A and for the initial visit with MFB to Building C, but in building B, the team was simply given access to the building as there was no manager available.

Building A, detailed in Section C.1, was found to be exemplary with virtually no noticeable faults. It also had the systems and policies in place which should prevent major issues from arising. Not only was the current condition of the building very good, the staff was found to be well aware of the state of their building and quick to both find and fix any problems as they arose. When the team arrived and spoke to the manager, he immediately told the team that a fault had occurred in the evacuation system from the 7th to the 13th floor. This problem was identified during the building's biannual maintenance and procedures were put into place to ensure the safety of the occupants and to make sure that the occupants are aware of such procedures while repairs were made. This level of awareness and willingness to make the necessary changes quickly provides an excellent example of how building management should be approached.

Building B was found to contain several deficiencies which, when combined, created a potentially dangerous situation. The specific issues found during the site visit are detailed in Section C.2. The main source of these faults seemed to come from improper or nonexistent maintenance. For example, all of the portable fire extinguishers seen had not been serviced for at least two years, as opposed to the

required biannual checks. In Figure 12-1, the tag on the fire extinguisher shows that there has not been any maintenance on the extinguisher for about two years prior to the date of the visit. In some cases the fire extinguishers were missing altogether. The single stair in the building was required to be sterile, but there was debris found in the bottom of the stairwell which presents a hazard, especially if it were to ignite. In another case, the maintenance logs for the sprinklers indicated that the required maintenance had been performed, but a fault with the sprinkler running warning light was found each time for the past year and never seemed to be repaired. This fault has the potential for serious consequences. If the pump motor is running unnoticed, it could burn out leaving the sprinklers inoperable in the event of a fire.



Figure 12-1: Overdue Maintenance on Fire Extinguishers in Building B

The issues found in Building C were more serious than those in B, and had the potential to be disastrous. The results of the site visit are detailed in Section C.3. A lack of communication seemed to be the primary source of these deficiencies. The building utilized staged occupancy, which means occupancy had started while the construction workers were completing the building. This practice is not necessarily dangerous, but it must be clear to construction workers that safety requirements for an occupied building are different from those for a construction site. It is common practice for workers on a construction site to prop open doors to make it easier to move around. This, however, affects compartmentalization in an occupied building.

This building in particular relied on a single stairway, pressurized to keep smoke out. With the doors open this system would not work properly, causing the only exit from the building to become unusable as it fills with smoke. The issue of certain building areas changing use due to ongoing construction could also be seen with the storage of trash in the first floor lift lobby. Figure 12-2: shows bins of debris on one of the car park levels. Most of the carpark levels did not have an automatic sprinkler system, which were deleted as part of the alternative solution for the building. This deletion did not account for the kind of fuel load which was present as a result of the rubbish.



Figure 12-2: Rubbish in First Floor Lift Lobby of Building C

Because Building C was the place of residence for the team, the process of forcing change on the building was observed easily during the course of the project. The rectification process involved several participants, including MFB, the Municipal Building Surveyor (MBS) for Melbourne, and Worksafe. It took approximately two weeks for significant improvements to be made to the building's use. Part of this delay was caused by the complexity of the situation. There was confusion as to who had authority due to the dual nature of the building as both a construction site and an occupied residential building. The quickest organization to get results was Worksafe, which was able to have a 45 kilogram Liquid Petroleum Gas (LPG) tank placed near

an open fire door to the stair, as shown in Figure 12-3, removed within 24 hours of the filing of a complaint. Eventually, through the combined efforts of the MFB and the MBS, changes were made to the way the building was used, but these changes were slow in coming.



Figure 12-3: LPG Tank in Lift Lobby Outside Open Door to Stairway in Building C

12.1.2 Commercial Buildings

The process of performing the case studies for the commercial buildings was generally the same as that for the residential buildings. Using the design documentation, key policies required to maintain the effectiveness of the fire safety solution were identified. The level of compliance with these requirements was then determined by visiting the building and talking to the building manager.

Three commercial buildings were studied. These were all large warehouses and shipping companies. A common feature throughout these buildings was that the sprinklers had been deleted from the design. Instead of automatic sprinklers, these buildings often relied on occupant behavior and management policies to minimize the

growth of a fire. Overall, the commercial buildings were found to be more compliant than the residential buildings visited. There were faults found at each, including some very serious issues at Building F.

Building D, detailed in Section C.4, had a few minor issues. Because of the lack of sprinklers in the building, there were many constraints placed on the manner in which paper rolls could be stored in order to justify the deletion. One of these was that paper rolls could not be stacked any higher than 4.8 meters. For the most part this was being held true in the building and policies were in place to maintain it, such as signs at the maximum height allowed. There were a couple stacks that were as high as 5.2 meters, but this seemed to be an exception rather than a regular occurrence. Other than this the building was largely compliant. All the essential safety measures such as portable extinguishers and hose reels were being maintained. There were also evacuation and emergency procedures posted in the building.

Building E, detailed in Section C.5, was found to be reasonably compliant and well managed. The primary area of concern for the building was the distribution center which had been increased in floor area from 16,670 m² to 18,730 m², crossing the 18,000 m² regulatory threshold for required automatic sprinkler systems. The sprinkler system and automatic fire detection systems had been deleted in favor of human intervention policies. The design specified that the means of detecting and reporting a fire would be done entirely by employees working in the building. When the team visited, the building manager was unaware that there was no automatic fire detection system. This has the potential to result in a breakdown in communication, where a worker might call the fire brigade and not notify management or might evacuate without realizing that he/she needs to notify the security gatehouse so that they can sound the alarm. Because the alarm and evacuation system is manually activated, a breakdown in communication could result in a much more dangerous scenario than the design accounted for. Other than these issues, the building was well managed and run in accordance with the requirements of the FSE.

Building F was found to have some very significant issues, which are detailed in Section C.6. There were several problem areas which could create problems in the event of fire. One was obstructed egress paths. There was one fire exit which had

large stacks of wooden pallets blocking it, as shown in Figure -12-4. Additionally, there was a lot of paper in the printing room, making egress more difficult there. The more significant issue was fuel load. The fire engineering analysis specified that the storage in the warehouse be kept below four meters in height and under a certain volume, which was calculated to be four rows of shelving. When the team visited the building it found that there were five rows of shelving. Additionally, the team measured the height of the goods on the shelving to be between 5.6 and 6 meters on two of the rows. These were the highest point at which the containers were stored, although all the shelves had goods stored higher than four meters as the top shelf itself was just less than four meters high and each row had goods stored on the top shelf. This additional fuel load could result in a fire which is much more intense than what the building was designed to handle.



Figure -12-4: Obstructed Exit in Building F

12.1.3 Types of Changes

In examining the deviations between a building and its design requirements, there are a great number of subtleties necessary to understand the impact that certain changes can have. These include the ways in which a building can change in usage and how the changes affect the requirements. Many of these distinctions overlap, but still provide a way of categorizing and understanding the usage changes.

Understanding these subtleties is necessary to improving communication and design techniques to solve existing usage deviations and prevent future ones.

12.1.3.1 PBD and DtS Requirements

The issues found in these case studies generally fell under one of two categories: ones breaking general requirements posed by the DtS provisions, and ones breaking building-specific requirements of the PBD. Many of the issues found throughout the case studies fell into the former category. These issues were not necessarily associated with PBD but rather were indicative of the issues involved with enforcing building regulations in general.

Although many issues were found with buildings which could compromise the fire safety solution in a building, often these areas of non-compliance were associated with the DtS provisions. The engineer usually makes the assumption when designing the alternative solution that the building will comply with the building codes, but this assumption is made for any building, whether it utilizes PBD or not. This included a wide range of issues. One example was the storage of goods in Building F, where the fuel load was much higher than anticipated at design. This particular requirement, however, came from the BCA, not from the fire engineering report. Another example of a DtS violation is the maintenance lapses in Building B. These problems were not a direct result of issues with PBD, but the possible effects were compounded by the fact that the buildings used alternative solutions to eliminate some of the fire safety measures. The increased fire load in Building F was made more serious by the fact that there were no sprinklers to help control a fire. The same is true in Building B, where unresolved maintenance issues with the sprinkler system could cause it to fail in a fire, making it even more difficult to escape. Because the PBD aspects require that the DtS aspects comply with code, the calculations that justify the PBD aspects may become inaccurate.

The other category of issues was those that violated assumptions made by the engineer when designing the alternative solution. An example of these types of issues was the storage of the paper rolls in Building D. It was clearly stated in the report that the paper rolls needed to be stored in a certain manner, which was not always case

when the building was visited. The single stair apartments have more stringent requirements on the stairs, where the fire doors must not be chocked open (as they were in Building C) and there must not be excess combustible material in the stair (as there was in Building B). These types of problems are more unique to PBD buildings, where the requirements are unique to each building and must be maintained in addition to all of the DtS requirements.

12.1.3.2 Situation Changes

One way in which changes can occur is due to a new or altered situation in which a building is used. These newly added or altered situations are ones that were not anticipated at design, and can result in defeated fire safety systems. It is also possible to have the same situation, but with a change in usage, which can also result in an unsafe building.

From the case studies, Building C provides the best example of an additional situation, where an apartment building had the additional situation of a staged occupancy, which added construction debris and resulted in building practices rendering the stair pressurization system ineffective. In this instance, the FSE, Subject 8, was not involved with plans to have a staged occupancy at design, so provisions acceptable for all stakeholders for the staged occupancy were never created. This change was due to the addition of a new situation, construction, to the previously planned residential apartments.

An example of a changed situation comes from one of the fire services interviewees (Subject 6), of a factory that burned after its contents were changed from non-combustible metal car parts to a variety of flammable items, including 150,000 liters of motor oil. In this case, the usage situation was changed from a warehouse storing non-combustible materials to a warehouse storing combustible materials. This was a change in usage situation was due to a change in ownership.

Changes to the usage situation of a building, either by adding new situations or changing the existing one, can have a significant effect on the safety of a building, as highlighted in both of these cases. However, the possibly harder to detect changes are

those that do not include a change in usage situation. From the case studies, Building F was the clearest example of a building where the usage changed from the design, but did so in a subtle manner without an obvious change in usage. The major problem with Building F is the fuel load in the storage area, where the building, when in use, contained far more material than the original plans called for. However, the change itself is relatively small, in that the building still stores exactly the same contents, and only differs in the quantity and arrangement of the material stored. The significance of this is that it is even harder to detect this sort of change, as it may appear to outside inspectors or building managers that the building is being used exactly as originally planned.

12.2 Building Owners and Managers

Communication to building owners and managers is a central focus of this project. However, due to the numbers of parties involved with a building and the number of influences on management, communication is one of the most complicated areas of the project. Communication lapses can occur in a number of different circumstances for different reasons. Of particular interest to this project is the owners/managers' awareness of fire safety needs, which can significantly change the level of compliance with fire engineering requirements. The examples in the next sections will show some of the issues that the team found and how they relate to the owners and managers. In order to determine how management influences the effectiveness of fire safety in a building, the project looked at a spectrum of PBD implementation qualities. This allowed the team to determine which areas of knowledge are necessary for effective building management. Building owners and managers can use buildings with well-implemented management procedures as an example.

12.2.1 Interview Results

The primary sources of information gathered to gain perspective on the roles of building owners and managers were the interviews performed as a part of case studies, as well as interviews of the various professionals involved in the building process. There were two interviews performed during the residential case studies, and an early interview in which the team played a less active role. This was because the accompanying MFB inspector had more immediate concerns due to the safety issues

with the building. Outside of the case study-specific interviews, there were thirteen interview subjects, in a range of fields, including four private FSEs, three fire services personnel from other Australian states, and six building surveyors. Due to the small sample sizes, it is not possible to consider statistical trends within this sample as statistical significance is not possible within from these interviews. For further reference, the general list of questions and topics is located in Appendix B, and the notes from individual interviews are in Appendix D. Due to confidentiality concerns among the interview subjects, citations to particular subjects are made using the numbering used in Appendix D.

In most cases, the building manager was present when the site visits occurred and escorted the team through the building. During this time, the team asked questions about management policies, evacuation procedures, and maintenance policies. Building B was the only building which did not have a manager on site during the site visit. In this case, a phone interview was performed after the actual site visit occurred. Follow up interviews occurred for several of the other building managers.

The set of interview questions and topics evolved during the course of the project, as the interviews were frequently rather unstructured or tailored to specific people. In many cases, the team could gather more information and examples by encouraging subjects to elaborate on questions. Many subjects were more experienced in some areas than others, which required more targeted questions. The questions in Appendix B were used as a general guide for the interviews, but the actual questions asked depended on a number of factors. Several subjects, particularly those in fire services, were quick to supply examples and experience with PBD, and these interviews did not require a significant degree of probing for more information.

12.2.2 Management Implementations

The case studies indicate that there is a breadth of management implementation techniques, with varying levels of compliance with fire engineering requirements. This section provides comparison between what good management looks like, and what can go wrong under bad management. It should be noted that while both

extremes of management are present, the proportion of implementation quality in Victorian buildings in general cannot be determined from the case studies.

12.2.2.1 Compliant Management

The differences between managers can significantly influence the effectiveness of a building's fire safety systems. Because the specific management policies come from the fire engineering requirements, any compliant building will have implemented these policies correctly. Of particular interest in the analysis of compliant management (determined during the site visits) is the approach taken and attitude towards maintenance. Analysis of these sections will allow the team to determine what makes effective management work when compared to non-compliant management.

One of the residential case studies, Building A, management was particularly effective in ensuring that all of the fire engineering requirements were maintained. In this building, not only were almost all of the systems in place maintained properly, but those that were not working were fixed very quickly. In the initial selection of this building, project advisors knew through previous experience living in the building that management would be very proactive in fixing any discovered problems. The site visit and interview with the manager (Subject 7) confirmed all of these expectations.

The interesting conclusion to be drawn from the interview with the Building A manager was that the manager had very little understanding of how the fire systems worked. He also had never seen the fire engineering report for his building and knew nothing of its existence. His primary source of information for the building was the set of building operating manuals provided by the developer, which specified in detail what he must do to keep the building compliant. He was informed by his body corporate that he must complete the safety system checks as per the requirements, both due to regulatory and safety concerns, but the fire safety reasons behind the requirements were never explained to him. For example, when the group asked him if he knew why the fire doors needed to be kept closed, all he knew was that he was keeping his building safe. There was no understanding of what a fire door actually does to help with safety (Subject 7).

The safety and maintenance checks were outsourced to maintenance contractors that knew the technical aspects of the safety systems so that the owners and managers would not have to deal directly with these details. The manager's mindset was that if he kept doing these checks then he would get to keep his job and keep getting paid, while keeping the building safe at the same time. The body corporate also performed audits to ensure maintenance was performed correctly and problems fixed promptly. Another interesting observation was that cleaning, maintenance, and repair for all the systems was outsourced to maintenance contractors and therefore there were no employees under the manager. The people that do the cleaning and system checks report to him if they find something that is not working properly and he then gets the appropriate repair person to fix it. One particularly notable accomplishment of the building management was the meticulously detailed and organized documentation of all checks and maintenance performed (Subject 7).

The managers and the body corporate were very reliant on the contractors the company hires to take care of fire safety systems because they had little knowledge of the technical aspects of the systems. The communication with contractors appeared to be effective in this building, as management was aware of any existing problems and could fix them quickly. Because the building was relatively new, the contractors performing the maintenance of the building were the same as those that originally installed the systems, so no further evaluation methods of the contractors were in place. The reason behind the choice to use these contractors was based on previous experience and reputation (Subject 7).

In the best building of the commercial sites, Building E, there was an active effort to keep the building clean by removing all combustible debris from the area. The manager escorting the team during the site visit informed the team that company staff performed frequent housekeeping between shifts, which helped avoid excess combustible materials, a requirement of the PBD documentation. The management also performed evacuation drills and had had two emergency evacuations, which effectively tested the emergency plans.

The primary PBD requirements of Building D were the storage of rolls of paper, which could not be stored over a certain height. Procedures were put in place by management to keep the rolls of paper from being stacked too high. This included signs posted throughout the building to inform the workers that the paper should not be stacked over 4.8m. These signs were located at the proper height so employees stacking the paper knew the highest point at which they could stack the rolls. The management had also gone through the dimensions of each type of roll used and determined how many could be stacked within the height restriction. There were some stacks of paper higher than 4.8m, but not significantly over the limit. There were only a few of these exceptions, as the majority of the stacks were within the limit. The managers were not aware that some of these exceptions existed, as the only means of quickly measuring the heights is to count rolls and compare heights. The management also responded positively to this by suggesting ways to prevent this from occurring in the future, such as running wire at the proper height to make it physically difficult, or at least inconvenient, to store goods higher than allowed.

12.2.2.2 Non-Compliant Management

While there are only a small number of ways in which a building can be compliant, there are a large number of ways in which buildings can be badly managed. This section will describe the ways in which the management in non-compliant buildings in the case studies went wrong. Further analysis on influences likely to cause problems with management implementations appears in Section 12.2.3.

Building C, the single-stair apartment building with the worst flaws, allowed for an extended observation of management process to resolve deviations from fire engineering requirements. At the beginning of the time the team was on site, the management was notified of the problems with the building. One major difference between this building and the others studied was the impact of active construction on the building. This extra party made determining whose responsibility the fire safety matters were more complicated. The building had ongoing changes in the building which fixed some of the previous deviations found, but new issues were found during the course of the team's stay in the building.

Because of their role in the usage changes in the building, the awareness of the builders was an important consideration. The builders, even though they were responsible for some of changes occurring in the building, did not understand how this affected the safety in the building. The builders were unaware of the stair pressurization system and did not know the doors were vital to the building's safety. When the individual workers were approached and the nature of the fire safety system was explained (In terms of the safety risk posed directly to the workers themselves), they were more willing to change their habits. Unfortunately, the problems of propping the doors open were not solved this easily, as builders continued to find ways to defeat the door latching mechanisms until, after two weeks, the builders simply unlocked the doors. This case highlights that even after being informed of the importance of a safety requirement from both legal and safety perspectives, some people will continue to ignore simple safety requirements. It should be noted that during the entire process, every door had a sign labeling it as a fire door that must not be propped open.

Continuing with this particular case, the building manager was notified of the problems in the building through the fire brigade and the municipal building surveyor, and the actual procedure for fixing problems was more complex than simple notification. While the building manager, when notified by a brigade inspector, claimed that changes would be made in a timely fashion to the building by security staff he employed, these changes took much longer to actually come to fruition. This indicates a communication problem between management and the construction workers, however the exact dynamics of this relationship have not been fully observed. There are also indications that the problem is more significant. Fixing one of the more serious flaws in the building, a 45kg LPG tank near an open door to the stairwell, highlighted that a combination of broken lines of communication, lack of awareness of the building's condition, and the people trying to fix this problem were even misled. When the tank was said to be gone, it was actually moved to a different place in the building. The eventual solution for this problem was to involve an Australian workplace safety agency, WorkSafe, to force removal of the LPG tank.

In this example of worst case management, it is clear there are a number of ways in which a lack of awareness and communication resulted in an unsafe building. In this example, the primary aspect of awareness was of the significance of the changes to the design, as it was clear from signs on fire doors that propping them open is a fire hazard. From the observations over the course of the project, it appeared that policy changes to increase compliance with fire engineering requirements were motivated by continued pressure from several regulatory agencies rather than internal impetus to improve safety.

In another example the team interviewed the manager (Subject 9) of Building B. After this interview, performed after the inspection of Building B, it was interesting to hear what he knew about his building. The team had asked if he was aware of the fire safety systems and the necessary maintenance in his building and he said he was. This highlighted a discrepancy between management's perception of the building and its actual condition, as the site visit found a lack of maintenance on the fire extinguishers and an egress path blocked by garbage bins. This is a particularly worrying discrepancy, as this building had a notification of non-compliance with Essential Safety Measures requirements, and the notice should have been sent directly to this particular manager. The manager also said that they had outside contractors that maintained these systems and have been since the commissioning of the building. This manager claimed that maintenance checks and repairs had been performed on the correct schedule, though there were relatively significant flaws found during regular maintenance checks that had remained unfixed for over a year. While the team cannot verify whether the maintenance contractors had made any attempt to notify the manager of problems found during routine checks, the team can conclude that the manager is apparently unaware of the condition of the building.

Building F highlighted a different communication error, specifically the communication of the building's specific limitations to the managers. The manager was not aware, while escorting the team through the facility, of the fuel load requirements for the building, particularly the height and volume requirements. This requirement was specified because the storage racks shown on the initial plans indicated that storage volume and height would be very close to the DtS requirement for sprinklers. This requirement was on the occupancy permit, but directly cited a

table from the BCA and required that the building be an “excessive hazard.” It would not be possible to determine how to implement this requirement without finding the table in the BCA itself. This is a significant lapse in communication, which can in part be tracked back to the building surveyor, as the building surveyor would actually have written the occupancy permit. There is some uncertainty in exactly where all of the communication issues lie, however. The building manager either did not read the occupancy permit or did not understand the requirement, which indicates that either the building owners or building surveyor did not communicate the meaning behind the requirement. There appear to be other communication issues involved with this building, as the original usage assumptions on the plans as to the number of racks changed. The plans tentatively showed four long storage racks, which is near the threshold for DtS required sprinklers, but the actual building had five racks and storage on the floor. This deviation indicates that the initial usage assumptions were not conservative enough in estimating the storage capacity of the building.

12.2.3 Influences on Management Implementations

There are many factors which affect how building owners and managers make decisions regarding both the construction and the day-to-day management of their buildings. These influences include things such as cost, education, and insurance requirements. It is important to understand these influences and how they can cause a building to be managed in either a compliant or non-compliant manner. This section provides analysis based on a combination of case study observations and interviews with fire safety professionals.

12.2.3.1 The Cost of Fire Safety

There are several areas in which cost can influence the use of PBD in buildings. One issue is the tradeoff between higher initial costs to implement safety systems versus a very high cost in the case of a fire. Many of the interviewees noted that developers are afraid of installing more complicated fire safety systems, like automatic sprinklers, because of the high initial cost and the cost of maintenance. These same developers also tended to ignore the significantly higher costs of a fire in a building that is not well-protected. Even with pressure from fire services and fire

engineers to install more expensive and more effective systems, there is a significant hesitation to spend more money. The usual systems this trade off impacts are automatic sprinkler systems, which are complicated and have long-term maintenance requirements, but provide a significant level of safety when implemented properly (Subject 1, Subject 4, Subject 5, Subject 6, and Subject 8).

One specific example cited by an interviewee (Subject 6) was an industrial building that was being rebuilt after a fire. The building was manufacturing fiberglass poles and after the first fire which completely destroyed his building, the owner did not want to put sprinklers in the new building. The owner's reasoning was that after the fire he did not have enough money to be able to afford sprinklers. One would think after a catastrophic fire where a loss of approximately 17 million dollars was incurred, the owner would want to take extra precautions in protecting the next building he owned. As pointed out by Subject 6, sprinklers are an effective means to improve fire safety, even with their expense. They make the building safer, often allow other fire safety systems to be deleted, reducing the cost, and make the building more flexible in terms of use and thus easier to sell. Even so, building owners do not like the initial capital cost involved with these fire safety systems, and try to avoid installing them (Subject 6).

Another example of building for a cost was Building B. This building had the similar motive of cost. The owner of the building decided not to put in a garbage chute. The garbage chute may not seem to affect the PBD, but when there are excessive fuel loads in the hallway, such as garbage left in the hallway by the tenants, the egress path could become compromised. While there were only two bags of garbage in the hallway during the visit, it should be noted that the cleaning staff was servicing the rooms and hallways at that time. This could have made the small amount of garbage seem smaller than it actually was prior to the regular cleaning. There were procedures in place to prevent trash from being left in hallways. The manager (Subject 9) informed the team that if the cleaning staff found any trash left outside the door they would have to report it back to the manager. The manager could then take action against the tenant. The manager reported trash left in hallways as a regular occurrence, and he was receiving many complaints from the cleaning staff.

12.2.3.2 Education

The education or knowledge of the building owners/managers at design time varies depending on the project and the developers. In some projects, the clients for the fire engineers are quite knowledgeable about what PBD is, how it can affect their project, and what concerns are important. This level of knowledge varies greatly, and the perceptions of PBD change depending on the client. Some see PBD primarily as a way of cutting costs, particularly seen in cases of reverse fire engineering, where fire engineering is simply a way of rationalizing previous decisions. It has been the observation that the perceptions of PBD depends on the age and the experience of the developer, where older developers are more likely to see things in a prescriptive, black-and-white manner where deviations must be fixed sooner, and younger developers see PBD as a get-out-of-jail free card that can allow for cost cutting (Subject 1, Subject 6).

Once the building is finished, the level of education of the building manager did not seem to be as big an influence as one might think. There did not seem to be any difference between compliant and non-compliant managers as far as their knowledge of fire engineering and the reasoning behind the various performance requirements. Many building managers said they had little technical background and relied on contractors to actually carry out the maintenance requirements for the building. The exception tended to be in the commercial buildings, which had on-site maintenance staff and occasionally engineers, who displayed a greater understanding of fire safety matters. The technical maintenance of the systems relating directly to fire safety, however, was always performed by outside contractors. Several interview subjects suggested that more education would make building managers more aware of the importance of meeting the requirements put forth by the FSE and therefore more willing to meet those requirements (Subject 4, Subject 5).

12.2.3.3 Insurance

One outside party that can affect the building process is an insurance company. Of particular interest to this project was the understanding that insurance companies have of PBD. From the experiences of the majority of interview subjects,

insurance has little effect on most building designs, with the exception of buildings where property protection is important. The team found out that the insurance companies were not affecting the designs, but the team was unable to interview any insurance companies to find more information due to time constraints. Some examples provided of these were art galleries, where the paintings were the primary protection goal, and aircraft hangars, where the airplanes inside the hangar were worth several times more than the hangar itself. In these cases, insurance companies are more likely to get involved early in the design process to ensure that adequate fire safety systems exist to protect the property stored in the buildings. In some of these cases, insurance companies would provide a detailed list of fire safety systems that must exist to keep their insurance policy (Subject 3, Subject 4, Subject 5, Subject 6).

The conclusion drawn from the interviews concerning insurance is that while insurance companies do have an effect in some instances, the majority of insurance policies are not dependent on the fire safety systems, as long as the building is code compliant. In such instances, there are no insurance pressures to keep the PBD systems working properly. Interviewees noted that in most cases the insurance policies and premiums are exactly the same regardless of the quality of the fire safety provisions (Subject 1).

Interviewees noted a mix in the level of education that insurance companies had concerning PBD and its effects, as there were some that were aware of its uses and extra requirements, but many did not realize the significance of fire engineering in a building's safety. In an example cited by one of the interview subjects (Subject 5), an insurance company refused to allow a PBD solution which would have provided better protection in favor of the DtS solution as it supposedly meets code better. There were other aspects noted by building surveyors interviewed that should be important to insurance companies, such as the legal requirements for maintenance, and that building owners could become liable if a building burned due to negligent maintenance (Subject 4, Subject 5).

12.2.3.4 Public Pressure

Another influence cited by interviewees on how a building is managed is the visibility of the building to the public. The comparison was between a large, well-

known facility such as the Melbourne Cricket Ground and a warehouse in a seldom-traveled part of town. In the case of a large stadium, if there are any safety concerns or violations, there is a fear of significant repercussions due to public pressure. The rarely seen warehouse does not get any of this visibility. Especially in the case of businesses that depend on trade with the general public, buildings cannot have a reputation as being unsafe, which would theoretically lead to safer management practices (Subject 6).

This has an influence on the enforcement aspects of the process, as municipal building surveyors have found that building owners are reluctant to go to any sort of publicly recorded trial over a safety concern. This fear leads to many instances where building owners would rather fix an unsafe building than risk their reputation disputing the safety requirements (Subject 4).

12.2.3.5 Regulatory Requirements

One important influence on building managers' actions has been the regulatory requirements imposed by building codes and enforced by fire services inspections and municipal building surveyors. The source of their enforcement power is that it is illegal to not maintain a building to the requirements on the occupancy permit. However, while there are legislatively granted powers to force problems to be fixed, all of the interviewees involved with the process cited a lack of personnel to actually perform the policing. It was well-known by those in fire services and municipal building surveyors that a large number of buildings did not write annual reports on essential safety systems. These reports are legally required, but all interviewed cite lack of personnel to actually track down the buildings that do not complete paperwork. These sorts of problems in enforcing regulatory requirements make the influence of regulatory controls over buildings significantly weaker over building managers willing to ignore requirements (Subject 1, Subject 2, Subject 3, Subject 4, and Subject 5).

12.2.3.6 Building Surveyors

Another area noted as a problem in the building process was the building surveying market. Interviewees (Subject 1, Subject 5, Subject 12) cited a shortage of qualified building surveyors. Several noted a frequent lack of technical capability to evaluate fire engineered buildings, and a more pressing concern, that some building surveyors are unaware of the limits of their own fire engineering knowledge. This is worrying, as surveyors may be approving buildings based on an incomplete understanding of the fire engineering, particularly the subtleties of how systems are integrated.

The clearest issue was the small number of building surveyors, which results in some building surveyors issuing very large numbers of permits. As of April 2007, the Building Commission lists 484 building surveyors, with 31% of those that do not actively issue permits. Those that issued permits were issuing very large numbers of permits, with 11% building surveyors issuing over 500 permits in the past year. The average number of permits issued in a year by the average building surveyor was 303 permits. These numbers were cited by an interview subject (Subject 12) as an indication that there are a large number of building surveyors that churn through building designs too fast to thoroughly examine them or take the time to address the subtleties of the designs. This interview subject was of the opinion that only about a third of these active building surveyors were likely to be qualified to examine the more sophisticated fire engineered buildings. Combined with the observation that most building surveyors do not see buildings after the occupancy permit is issued, this shows a clear problem that building surveyors are unable to keep up with the amount of work while maintaining high standards.

12.2.3.7 Fire Safety Awareness

One influence on management effectiveness, initially expected by the team and others working on the project to be significant, was the level of fire safety awareness among building managers. It was expected that the level of awareness would be proportional to the safety of the building. However, Building A proved to be a counter-example for this hypothesis, as the manager (Subject 7) for the building with the best management had little understanding of fire safety matters.

In this particular instance, the manager of Building A knew, for example, that fire doors need to be kept closed because they were on the list of usage and maintenance requirements. He was aware that this policy was connected to fire safety, but did not know the role fire doors play in preventing smoke and fire from spreading into egress passages. He was also completely unaware of the fire engineering report done on the building. Even in this case, the building was extremely well kept, as the fire engineering requirements had been translated into operating manuals for the management, and the rules contained were rigorously followed.

In Building F, there was similar example of a lack of awareness of the fire safety systems, but in this case the manager was breaking an assumption the FSE had specified. The manager was unaware of the storage restrictions on the building, which did not allow him to store materials at a height of over 4m or a volume of over 2000 m³. The manager was also unaware of the occupancy permit which specified this requirement.

The manager for Building D was aware of the height requirements for the storage of paper rolls and that this was important because the building had no sprinklers. This knowledge seemed to be enough to make the management put the effort into implementing policies which would prevent goods from being stored improperly. They were also willing to put further controls into place when stacks of paper rolls were found to be too high. Based on their response, these issues seemed to be anomalies rather than a common occurrence. The managers also followed up with the site inspector at the MFB that took the team on the site visit with a letter and form. This letter and form indicated they will now be conducting monthly and daily checks of the safety measures in place and reporting them appropriately.

These examples seem to indicate that, provided the management for a building is aware of the fire safety requirements, they do not need any knowledge of the reasoning behind these requirements. Management for both Buildings A and D were

aware of the requirements for their buildings and had taken steps to ensure those requirements were met. The manager for Building F was not aware of the requirements for fuel load in his building and had serious issues as a result.

The fact building managers have little understanding of the technical aspect of fire safety requirements was confirmed through interviews. The general consensus of interviewees was that building owners and managers with technical knowledge are a rarity. They believed most were just doing what was required for the simple reason that it was required. Some of the interviewees indicated that if managers were to have more knowledge it would make them more likely meet the requirements (Subject 1, Subject 4, Subject 5, Subject 6).

12.2.3.8 Hierarchies of Responsibility

Another issue influencing the effectiveness of management is the number of people who have a role affecting building maintenance. The issue, highlighted by discussions with MFB personnel, occurs when it is unclear who should perform certain maintenance tasks, such as in buildings that have tenants. It may not be clear that a tenant was expected to perform a particular task, but the tenant may expect that the building owner or manager was responsible. In such situations, it is possible for certain tasks to be ignored by both parties (Subject 4).

Building C, the significantly flawed single-stair apartment building, highlighted how having complex management can make fixing problems in a building difficult. Because the building was occupied by both apartment residents and builders, when problems were detected, there was difficulty in determining whose responsibility it was to fix the problems. During this time, such issues as a 45kg LPG tank placed near an open fire door were not addressed by either the building management or the builders. The complexity of the situation also made it hard for even regulatory controls through the MFB to force changes.

A different way the relationship between managers, owners and corporate bodies can affect maintenance of fire safety systems is when there is pressure on managers to ensure that buildings operate cleanly and with no regulatory violations.

This can lead to very effective management, as with both proactive owners and proactive managers, problems are found and fixed very quickly.

In the case of the best residential building, Building A, the most significant reason for the level of compliance with fire engineering requirements was the pressure from the outside body corporate to follow rules. In both the interview with the manager (Subject 7) and the site visit, it was clear that a significant level of pressure existed on the manager to ensure the building met all of its maintenance requirements and that problems were fixed promptly.

The effects of large-scale ownership of buildings varies on a number of characteristics, as in some cases the buildings will be run to higher standards, and in some cases to lower standards. Some large-scale building owners will impose more stringent requirements on the buildings (Subject 11). These can show up in the form of audits and maintenance requirements, such as in the case of Building A and some large corporations, or more stringent safety system requirements in the case of some hospitals or buildings with high insurance requirements.

12.2.3.9 External Contractors

While building managers are in charge of maintenance for the facility, the actual maintenance, especially for specialized fire safety equipment, is frequently performed by outside contractors. As required by Australian Standard, the actual checks on the essential safety measures, such as automatic sprinkler systems and alarms systems, must be performed and logged on a regular (weekly, monthly, or annually) basis. Of interest to this project is the level to which external contractors are used, how they are evaluated, and how they communicate problems to management for repair. The logs that indicate when maintenance has been performed are useful as they can give a timeline when problems occur.

In building A, the example of effective management, the manager (Subject 7), said that the official policy of the body corporate was to have all maintenance performed by outside contractors. This maintenance included all plant services, essential safety measure maintenance, and housekeeping in public areas. The reasons

for this were primarily the technical nature of the maintenance checks and that there was no business interest in hiring employees. All case study buildings used similar external contractor methods for the maintenance of fire safety systems. As shown in building A, it is possible for external contractors to perform sufficiently well for a building to be safe with otherwise effective management. This manager did note, however, that there are few means for a non-technical manager to evaluate the work of these maintenance contractors, so if problems are missed, there is no means of alternative detection.

In a situation where the management is less effective, it is possible for maintenance checks to detect issues in systems, but these may not be acted on by management. The best example of this is in building B, one of the single-stair apartments, where there was a problem with the sprinkler pumps for over a year. The particular problem was that the indicator alarm and light for the sprinkler pumps was not working, and the sprinkler pumps frequently were found to be running. If left unchecked, this could burn out the sprinkler pumps, crippling the sprinkler system. This flaw was noted in the maintenance logs for over a year, but there was no evidence of work done to fix these problems during this time. The fact that the owner was completely unaware of these issues seems to indicate that the contractors were simply not reporting the faults to the manager because they were written in the logs.

Interviews showed that contractors are a major source of concern in actually performing the maintenance on fire safety systems. One reoccurring issue is the number of contractors available, which is far less than necessary to actually complete all the work available. This frequently results in checks and maintenance not occurring. There is a solution to this problem already in use in some buildings, a system that places maintenance logs in a computer database that can be accessed offsite. With the data stored in this manner, it is easy to determine how much work has been done and recorded properly, all displayed in convenient statistical form. While it cannot verify if the work listed in the log was actually done, this sort of documentation does provide a significant indicator to building managers. This system also provides a financial measurement for building owners, as the owners are paying for all of the scheduled maintenance to be completed, not some smaller fraction. This allows building owners a way to evaluate maintenance contractors beyond reputation

alone. The statistics for the actual maintenance rates are fairly concerning, however, as only a fraction of the maintenance paid for by building owners is usually done. Maintenance contractors are becoming aware of this system, and will make sure that more work is completed on buildings that use this system. While it does not actually check work performed, it does provide a level of accountability among contractors that motivates improved maintenance (Subject 12).

12.3 Communication

In order to understand the background for the current situation of PBD implementations, it was necessary to understand the ways in which communication occurs between the main parties involved in the building's design and use. Of particular interest to this project were the communication mechanisms that handle usage changes. In order to examine how recorded information passes between parties and communication mechanisms, an examination of the documentation was important.

12.3.1 Changes in Use

The primary focus of the research in this project was to evaluate the extent to which changes occur in a building's use that undermine its fire safety systems, and of particular interest is finding what mechanisms detect these changes. Because there are different situations in which usage changes occur to a building and through which fire safety is evaluated, this section groups changes in use by the mechanisms involved with detecting and fixing problems. Of particular interest in each type of change was how the change could actually be detected by parties outside of building occupants, and what action can be taken to ensure that usage changes do not hinder fire safety systems.

12.3.1.1 Changes in Occupancy Classification

The interviews highlighted a procedural mechanism to reevaluate a building when it changed use, but only when a building changes sufficiently to require a

modified occupancy permit, frequently due to a change in occupancy classification. The common change cited by interview subjects was between offices, retail and apartments, which clearly change the occupancy classification along with several of the major assumptions underlying the fire design. The sorts of changes that are not picked up in this process are those that do not change the classification, covered in Section 12.3.1.3, and the ones where the lines between classes are less clear in practice, such as between class 2 apartments and class 3 hotels, covered in Section 12.3.1.2.

All of the interviewees cited the more detailed mechanism that exists to deal with an occupancy change as being more effective in involving outside parties to evaluate the changes. When a change requires more permits, then the relevant building surveyor reassesses the building with the new usage or modifications, and may even involve an FSE to determine the effect on the fire safety needs for the building. The more extensive review from outside parties allows this mechanism to more effectively deal with usage change in a building, and in its proper usage, prevents the problems that occur due to other changes in use.

12.3.1.2 Subtle Changes in Occupancy Classification

One flaw in the process, noted by several of the interview subjects, was when there is a change in the usage from the stated design that would technically change the occupancy classification, but is too subtle for regulatory processes to identify. A common example of this sort of change is between Class 2 and Class 3 buildings, which are long-term residential homes and short-term hotels, respectively. The code is clear in the distinction, but in practice, the line is much less clear, and these changes were seen in examples cited by interview subjects during case studies. In the case of the differences between Class 2 and Class 3, there were many examples of situations where a building was listed as a Class 2, but the actual occupants were there for very short periods of time making the actual use more like a Class 3 (Subject 1; Subject 4).

In one case, Building B was listed as Class 2 apartments, but had a minimum stay of two nights, and in some places was even described as a hotel. Observations of interviewees confirmed that this was a common occurrence, and it is not unusual to

have a situation where an apartment is treated as a hotel room and occupants are even told to say that they live in the room permanently if asked. This indicates that owners are aware of the change from the listed occupancy, but either do not care or do not understand the reasons behind the difference in classification.

This sort of change does have an effect on the assumptions underlying the fire safety systems, as familiarity with the building is a common requirement in many fire engineered safety systems. Municipal building surveyors, Subject 4 in Appendix D, list hotels among the highest risk buildings, along with nightclubs and bars, but a Class 2 building could escape more regular inspections.

12.3.1.3 Changes without Classification Change

The most worrying changes to building usage noted by interview subjects and in case studies were buildings with changes in use that did not change the occupancy classification, but did change the assumptions underlying the fire engineering. A very common example cited by interview subjects was in the case of a warehouse with a change in contents, and thereby a change the hazard level.

Subject 6 provided one particular example that resulted in a fire. A warehouse was fire engineered to require fewer safety systems (no automatic sprinklers or smoke detection system with brigade notification) because the intended contents consisted of noncombustible metal car parts. Later in the building's life, its contents were changed to a variety of combustible items, notably including 150,000 liters of motor oil. This was followed by a fire. This fire was extremely costly, as the burning oil spread throughout the building and to the outside, where it destroyed several large trucks and a packing container. The lack of automatic brigade notification meant that intervention took longer, and the fire was significantly harder to fight. The total damage was \$25 million. Subject 6 estimated that if the correct sprinkler system and notification system were installed, the fire would likely have been isolated quickly, with about \$50,000 in damages.

The overwhelming conclusion of the interview subjects was that there is no effective system to detect and compensate for changes. The sole means of detection

of problems for fire services is complaints from occupants. However, the occupants are unlikely to have the knowledge necessary to recognize these issues. Private building surveyors and FSEs have no input here at all, and will only be notified of changes if the change is picked up by fire services due to complaints. This was the consensus of all the interviews of FSEs, building surveyors and fire services personnel (Subject 1; Subject 4; Subject 6).

Identifying a change in usage that breaks fire safety solutions on a large scale is difficult due to the lack of identification mechanisms. In Building C, the flaws were picked up by a fire safety engineering professor who coincidentally happened to live in the building. In another instance, Subject 8 complained about policies in a building he was working in when he discovered similar usage flaws to those found in Building C. Interviews confirmed the team's observation during case studies that the changes that do get picked up are often ones spotted by a whistleblower or other knowledgeable person who occupies the building. In these cases, it was fortunate that aware fire engineers were involved with the buildings, otherwise these issues would likely have gone unnoticed.

12.3.1.4 Changes in Ownership

An issue cited by many of the interview subjects as being likely to cause a loss of information concerning building safety is the sale of a building. When the building changes owners, some of the knowledge from the design process that the original owners have may not transfer to the new owners. The other change that can occur is if the building is bought by an owner that is less conscientious of the fire safety requirements of the building.

In some cases, cited by interview subjects, some of the depth of knowledge of certain fire systems was lost in the transition, with a common example being automatic sprinkler systems. While automatic sprinkler systems are very effective, they come in a variety of forms and one may not be as effective if the hazard changes. Owners, especially those new to a building, sometimes think that sprinklers are a fail safe fire safety measure which gives them the freedom to do as they wish with a building. Owners often use automatic sprinkler systems to justify changing the

hazard level of the contents in a building. While an owner may pay enough attention to fire safety to note the sprinklers, they do not always know about the limitations of the system. A more extreme example occurred in the previously cited warehouses with changed contents, as the \$25 million warehouse fire was a case where the ownership had changed. In such buildings, which do not have the fire safety systems in place to deal with increased hazards, the fire engineering places limits on what can be stored in the building, but it is necessary for the building owners to check on these limits (Subject 6).

One mechanism mentioned by Subject 1 as a means of evaluating a building when it changes ownership is due diligence, which is a requirement on building owners to go through the process of finding all of the background information on a building. Regardless of whether it is a fire engineered building or not, information as to what the important fire safety requirements are, should be identified through this process. The difficulty, according to interview subjects, is in the lacking of building owners that actually go through this process in sufficient detail to identify the more subtle fire safety requirements. The proportion that perform due diligence is very small, estimated at 20% by Subject 1. One reason for the small number of owners performing due diligence is that if issues are discovered, they can result in the cancellation of the sale.

12.3.2 Communication Mediums

In examining the communication that occurs during the building process, it is important to examine the actual mediums by which information is distributed. The primary written documents in the building process are the fire engineering reports and the occupancy permits. The fire engineering report is the document created by the FSEs who designed the PBD, and must exist for all fire engineered solutions, which makes it a primary document in the transmission of fire safety requirements. The occupancy permit, a shorter document prepared by the building surveyor, is issued to all buildings regardless of whether the building includes fire engineering. This is the more visible document for each building, and is worth examining as a part of this project as the permit is meant to provide information to the building manager.

12.3.2.1 Fire Engineering Reports

Fire engineering reports contain the analysis and solutions for a building's PBD aspects. The essential parts are:

- A list of areas in which the design varies from the DtS requirements of the BCA.
- A list of alternative methods of meeting performance requirements.
- Rationale for each of the relevant performance requirements.
- Analysis to prove a building meets performance requirements, usually including quantitative analysis and fire scenario modeling.

There are several other pieces of information that need to come out of the fire engineering report in order for its information to be useful to other stakeholders. In general, these are the assumptions underlying the analysis, with several specific areas:

- Occupant characteristics
- Contents of the building (fuel load, distribution, special circumstances)
- Usage requirements
- States of fire safety systems

These areas were ones that should be examined not only during the technical analysis, but also when determining management policies, as it is imperative that these assumptions remain accurate.

The ability to identify the useful information in a report is critical to be able to begin to implement the correct maintenance policies. The team, as students not trained in the specific technical area of fire safety engineering, was able to effectively read all of the reports used as case studies to extract the important usage information. This is not to say that all of the reports presented information in a way that made this process easy, as the quality of presentation varied significantly. It is important to note that in the analysis of the reports, for the purposes of this project, the fire safety design and analysis is assumed to be technically correct, and this area of concern is focused purely on the reports' ability to communicate important safety information.

In the best reports, all of the assumptions behind the design modeling were carefully listed and clearly labeled. Background on each of the design considerations and the modeling process were included to allow for easy understanding of the

process. The usage requirements and necessary management policies were clearly written and listed as well. If a non-technical person were to read the report, it would at least be possible to find these important sections, even if the majority of the quantitative analysis is beyond their abilities.

The worst reports were much harder to read, and frequently the usage assumptions underlying the design were much harder to find. In these instances, it was necessary to scour the modeling sections of the reports to find what could be very important requirements, like keeping doors closed. Certain requirements might be mentioned in a separate requirements section of a document, like a reliance on trained staff as a fire safety system, but the significance of such a requirement would not always be apparent until reading the modeling sections. In these cases, it was clear that no one who was not able to understand the modeling sections would be able to understand the usage requirements from the fire engineering reports.

The team's observations of the ease of understanding fire engineering reports were consistent with comments of interview subjects, who reported that the majority of information contained in a fire engineering report will only be useful to a fire engineer. The experience of fire services engineers who review the fire engineering reports indicates that most reports that pass review will contain the required information, because it is required for approval. The presentation varies, in their experience, similarly to the reports seen during the case studies during this project (Subject 2, Subject 5).

As for the ability of the fire engineering report to communicate important usage requirements beyond the initial design stages, case studies and interviews with fire services personnel indicated that the fire engineering reports never had an impact on the day-to-day management of buildings, and that building managers did not have any awareness of the report. In the case of Subject 7, the manager for Building A, there was no awareness that such a report existed.

It is particularly important that the building surveyor be able to understand the fire engineering report, as he/she is the one responsible for evaluating and approving it. While building surveyors must have certain fire safety training in order to evaluate

a design without the aid of an FSE, many of the FSEs and fire services personnel interviewed indicated that the actual knowledge shown in practice by building surveyors is significantly less than what their credentials might indicate. The other area highlighted where building surveyors lack knowledge is in the awareness of their own expertise. Some building surveyors were reported by interviewees to have thought they understood much more than they actually did, which can lead them to make evaluations themselves rather than consulting an engineer. This is a particularly difficult issue, as it is easy to write a report that could make a design look sufficiently safe, but there could be problems lost in the complexity of a design (Subject 6).

12.3.2.2 Occupancy Permit

The document that plays a greater role in the communication between FSEs and the building managers and owners is the occupancy permit, which lists the essential safety measures that need to be maintained. The occupancy permit must also be displayed in the building and available within 24 hours if requested by a brigade inspector. Actual occupancy permits are much shorter than engineering reports, usually between one and ten pages, and the focus is specifically on what must be done as a matter of law to keep the building safe. Fire engineered buildings may reference the fire engineering report in the occupancy permit, but the fire engineering report does not have to be with the occupancy permit.

As a means of communication to the managers, many of the building managers, building surveyors and FSEs cited the occupancy permit as including the necessary information to create maintenance policies and requirements to keep the building use from changing. However, the actual permit appears to play a smaller role in some cases than thought in actually educating building managers, as indicated by the case study of Building A and conversations with Subject 7. In this particular case, the permit itself was not used in the day to day management of the building. Instead, there were much more detailed manuals for building maintenance provided in collaboration between the developers, who build buildings with the intention of selling them upon completion, and the builders. These manuals were used to create management policies, so the occupancy permit was less important.

Because there is no standard format for an occupancy permit, there is a significant amount of variation between them which results in some occupancy permits being more detailed and easier to understand than others. An example of a well written occupancy permit was that for Building D. This permit included the requirements for all the essential safety measures in the building in an easy to read table. It also identified the performance aspects of the building and the associated requirements. The usefulness of this sort of permit was demonstrated during the site visit, when the permit was used to check the actual requirement for the storage of paper rolls.

At the opposite end of the spectrum was the occupancy permit for Building F. This permit provided very little actual detail on the requirements, instead referencing external documents such as the BCA, which the manager is unlikely to have readily available. This was particularly true for the requirements governing the volume and height of storage in the building. The occupancy permit merely stated that the building not contain “excessive hazard” and referred to the BCA to define what this meant. This made it difficult for the building manager to understand what was required and was at least partially responsible for the fuel load requirements not being met.

12.3.2.3 Operating Manuals

One additional area of documentation, noticed both in case studies and through interviews, was custom operating manuals for a building created at the completion of construction by the designers and builders. This documentation varied in completeness, and was an option available to developers during the design and construction process.

In the one case study example in which the team observed the use of these manuals, Building A, the documentation was the primary means through which the building manager knew about the building’s usage and maintenance requirements. The documentation included ringed binders for each building in the complex, detailing all the specific information necessary to manage the buildings. This could then be used to inform external contractors of the building’s requirements, as well as

keeping track of the maintenance schedules. In this example, the manager did not have any understanding of the actual fire engineering behind the requirements. The custom documentation, to the exclusion of the occupancy permit itself, became the source of information necessary for fire safety in this instance.

Discussions with fire services indicates that this sort of documentation is commonly available as a service by the designers, but that it is not frequently taken due to the additional cost to the developers. The concept of operating manuals for a building, which detail in clear language the usage requirements, was described by Subject 1, a private FSE, as an effective way of communicating fire safety requirements for performance-based buildings. These manuals were currently being implemented in Singapore and were reported to be working well.

13 Conclusions & Recommendations

This pilot study is designed to show whether a problem of Performance-based Designed (PBD) buildings deviating from their usage requirements exists. During the course of the project, the team visited six buildings including three residential apartment buildings and three commercial warehouses. In these cases, the level of compliance with usage specifications from the fire engineering reports varied between buildings with significant usage deviations that could seriously affect fire safety, to buildings that were well managed and complied with the usage specifications. Building managers were interviewed as a means of determining the level of awareness of fire safety requirements and policies in place to maintain their buildings' safety. It should be noted that there were not enough case studies to be able to generalize the distribution of compliant buildings over all of Victorian buildings. In order to add more breadth to the project and examine some of the underlying issues behind PBD implementation problems, building surveyors, fire safety engineers, and fire services personnel were interviewed. In the absence of a statistically significant number of case studies, the interviews allowed the team to draw on the experiences of the interviewees to gauge the prevalence of PBD usage deviations. The interviews also gave insight into the building processes and influences that affect the final usage of buildings.

From this research, the team was able to draw a number of initial conclusions, as well as make a series of recommendations on areas that can be improved. Because this study has been designed as a pilot study, other areas for future research have been identified. There are a number of conclusions, with the most notable being that a problem with the current implementation of PBD in buildings exists. The other conclusions focus on more detailed analysis of the findings to characterize the issues found with the current PBD implementation. Based on the research done in this project, there are also areas where more research needs to be done, particularly on the long-term usage changes that occur with fire engineered buildings. While more research is necessary, the team was able to identify several methods to help solve the problems found with the current PBD implementation scheme. These include a number of procedural and enforcement changes, as well as some changes that can be

implemented by fire engineers and building surveyors to improve compliance with usage requirements.

13.1 Conclusions

Based on buildings examined as a part of this project, as well as discussions with fire safety professionals, there is sufficient evidence to show a problem exists concerning the implementation of PBD in buildings. One of the buildings examined contained flaws significant enough to present a significant egress hazard in the event of a fire, and two other buildings had deviations that could affect the assumptions underlying the design. The experiences of interviewees indicated that the problem is very widespread, and that great numbers of buildings with similar flaws could be easily found. The knowledge of these problem areas among building management was mixed, with a few building managers that knew of fire safety requirements, and some that even understood the fire engineering involved. There were building managers, however, that were unaware of usage requirements placed on the building, and in some cases they were unaware of logged problems in their buildings.

Beyond verifying the existence of a problem with the implementation of PBD in buildings, the team worked to characterize the nature of issues found and determine causes. These causes could be found through a mix of interviews performed and through comparisons between the case study buildings. Because of the complexity of the building process and the number of influences over a long period of time, there are some areas that the project could not fully investigate, such as the intricacies of the marketplace for FSEs, building surveyors and contractors, or any of the technical aspects of the designs. Of particular interest in this study are the systems in place to detect usage changes in PBD buildings, as well as what management policies actually work to comply with fire engineering requirements.

13.1.1 DtS and PBD Issues Overlap

There were a variety of problems found in the buildings, ranging from smaller issues, such as unclear signage, to significant problems, such as wedged open fire doors. Because of the complexities of fire engineering, it is difficult, as a part of this

study, to determine the effect of these changes to the overall safety of the building. There are, however, some notable characteristics as to the interactions of the usage changes with the design. One of the most common was the mix of compliance issues with both Deemed-to-Satisfy (DtS) and fire engineering requirements. In many cases flaws were found, but not precisely as a part of the PBD assumptions. These flaws, such as maintenance shortfalls or exceeded storage volumes, are not explicitly mentioned in the fire engineering reports, but are still connected to the fire engineering solutions. In the fire engineering reports reviewed, a common requirement was that all safety systems would be operational and working properly, or that all aspects of the building *not* involved with the PBD are fully DtS compliant. These sorts of requirements can mean that all of the DtS requirements can effectively be requirements for the fire engineered elements of the design.

The catchall requirements that all fire safety systems work and that all DtS aspects of a building comply entirely with DtS requirements make determining the aspects of the building that affect the PBD more difficult. In several of the case studies, buildings had deviations in the DtS areas, such as the increased fuel load in Building F, or maintenance shortfalls and impeded egress paths in Building B. These do not immediately change the assumptions behind individual PBD aspects, but rather change some of the general parameters underlying the fire scenarios. While these changes might usually be less significant in a DtS building, the alternative solutions were implemented to eliminate some of the DtS fire safety measures. The removal of redundancy in the fire safety measures compounds the effect of the smaller DtS violations, and can result in a less safe building.

13.1.2 Compliant Buildings and Proactive Management

While there were examples of buildings where the usage deviated from the design in dangerous ways, there were also buildings that were very well managed. For a building to work properly, a number of policies and attitudes must be in place. The most prominent characteristic of buildings that avoided significant problems was management that was proactive in both detecting and fixing problems. For example, in the best case building (Building A), there had been a significant problem with the warning system. What indicates that this was the best case building was that

management knew about the problem, coordinated its repair, and adjusted emergency procedures to compensate for the problem while waiting for it to be repaired. These building managers frequently had proactive owners and corporate bodies with proactive policies towards building maintenance, which gave the managers incentive to ensure the building complied with regulations. From all indications given during the case studies, there was effective communication with the contractors performing the maintenance, and no immediate concerns, such as reoccurring problems in the maintenance logs. In the best buildings, the managers were aware of what the maintenance requirements were, and how to implement them effectively.

13.1.3 Understanding of the Fire Engineering Report

An interesting finding from the case studies was that it is not necessary to understand any of the fire engineering in order to manage a building well. A building manager is unlikely to know very much of the existence of the fire engineering report, and in many cases, they may not know that their building is fire engineered. In the best case residential building, Building A, the manager relied on a series of fire safety requirements documented in the building's operating manual, but did not understand *why* the fire safety rules worked. For example, he knew that the fire doors must not be kept open, and that this was a fire safety issue, but he did not know that this is to prevent smoke spread through the stair. With a rule-following attitude and a well documented set of building requirements, it is possible for a manager to maintain a building without fire safety education.

13.1.4 Areas of Management Failure

While there were buildings that did comply with their fire engineering requirements, there were a number that failed in various degrees. In terms of management attitudes, if any of the major characteristics of well-managed buildings, such as an aware and proactive management, were absent, then the building tended to show flaws. In one case, the building manager was unaware of certain requirements placed on the building, Building F, and unknowingly exceeded them. In Building B, the manager was unaware of maintenance issues which had been occurring for the past year. The management of one building, Building C, even was misleading

inspectors to avoid fixing extremely simple problems. These problems indicate that it may not be unusual for building managers to be unable, for a variety of reasons, to improperly maintain their buildings.

13.1.5 Detection and Prevention Usage Changes

A more worrying observation, almost unanimously indicated by interviewees and apparent during the project's long-term case study, is that there is no effective method in place to detect subtle usage changes after a building has been built. Problems in the long-term case study were only detected by an occupant, who conveniently happened to be a fire safety engineering professor. Other detected usage changes were usually due to a knowledgeable whistleblower, or in one example cited by an interviewee, in the incident analysis after the building had a fire. What makes relying on knowledgeable whistleblowers more challenging is the level of persistence necessary to affect change in a building that may be dangerous.

Not only is there a lack of an effective means to detect usage changes after occupancy begins, there is a lack of feedback in the design process itself. FSEs almost never see the design after it has been accepted, on paper, by fire services and the client. Building surveyors usually do not see the design after the occupancy permit has been issued. This is a major problem in the design process that needs to be addressed in order to improve the use of fire engineering. Fire safety engineering is different from many branches of engineering as there is little ability to do a thorough prototyping and testing stage in the design. In other branches of engineering, many prototypes may be made before one is deemed ready to be a final product, and at each stage, any defects found feed back into earlier design processes. Fire safety engineering in buildings has the difficult requirement that the prototype must also be the final product, and there is more limited testing capability, as burning several buildings before approving a design is not cost effective. Because of this inherent limit on design feedback, it is very important to carefully monitor constructed buildings to ensure that they work properly. If the early use of the building is viewed as a test phase, rather than a final product, it would seem apparent that any problems found need to be fixed.

13.1.6 Shortage of Personnel

A major implementation issue cited by interviewees was the personnel shortage throughout the building industry. The regulatory bodies are particularly understaffed given the number of buildings. Interviewees from both the city council and the MFB indicate that there are not enough inspectors to inspect all the buildings needing assessments. Often, the town council is forced to focus only on high risk buildings and respond to complaints. It simply does not have enough personnel to be very proactive in ensuring that buildings are compliant. The same lack of personnel among building surveyors creates similar problems, as there are not enough well-qualified building surveyors to thoroughly analyze all the buildings seeking building approval. The result, in this case, is that some building surveyors are writing very large numbers of building permits, and simply cannot be spending sufficient time to be very thorough. There are a small number of building surveyors considered to be very reputable by others in the industry that get the bigger jobs, but there are not enough building surveyors to handle the volume of building projects. Interviewees also indicated that fire safety system companies are understaffed. Because of this, they tend to focus on new systems installations, which are more profitable, rather than their obligatory maintenance. This can lead to the required maintenance in buildings being neglected. These understaffing issues are significant in approaching any possible solutions, as simply getting more people, especially qualified people, into these positions is likely to be a very difficult proposition.

13.2 Recommendations

In addressing many of the problems found during the course of the project, there are a number of recommendations that the team has, both for further research and to make direct improvements. Because this project is primarily a pilot study, there are several areas where continued research is necessary, not only as a larger scale and longer term version of this project, but in a few more targeted areas. Beyond the need for more research, there are several solutions to problems that the team can propose even with the current level of research. These steps try to take into account some of the constraints on the process found during the research, particularly limitations on available personnel and funds. Several recommendations are

procedural changes which may need legislative changes to implement. These recommendations have been designed to minimize the amount of legislative action necessary in order to maximize the chances of successful changes to the system. Recommendations to improve the process from a design perspective have also been constructed to help gather information to further the research in this project.

13.2.1 Additional Research Goals

Of particular interest in a larger study will be the same areas targeted in this study: the level of compliance with PBD usage requirements and the approach building management takes to fire safety. One area this project cannot target is long-term compliance with usage requirements, as the buildings examined in this study were only a few years old at most. These buildings should be visited in several years to see if maintenance policies or building usage have changed. This will allow an understanding of what management policies and practices can actually be maintained over longer periods of time. If possible, it would be useful to follow buildings through changes in ownership, as this is a known time when the knowledge of special building features may be lost. Another area to examine is how contractors are evaluated over longer periods of time, as many of the buildings that were investigated were still using the contractors that originally installed the fire safety systems. A comparison between the compliance levels in DtS-only buildings and PBD buildings would also provide information as to what areas of non-compliance are specific to PBD buildings.

Another goal for more research should be to identify what promises made at design review are actually maintained once the building is in use. This information should include a comparison between specific DtS deviations and PBD solutions which rely on assumptions about human behavior and usage of the building. The goal should be to determine how effectively policies and usage requirements in the fire engineering report are being communicated and implemented. This information will be useful to both FSEs designing systems and design reviewers working with fire services. FSEs benefit by knowing what sorts of management policies they can require that will actually be implemented. This could help FSEs avoid including usage requirements that are unlikely to be effectively implemented. Engineers performing

design reviews would be able to use the same information to keep generally inaccurate usage assumptions from being accepted early in the process.

An example of one of these building-use-based research areas would be the use of staged occupancies in single-stair apartments, an area found during this project to be very difficult to implement properly. Further research would determine if there are any effective means by which this sort of staged occupancy could be implemented properly, and if not, FSEs in both private design and fire services review can be aware that this particular implementation does not work in practical implementations. If a developer tries to use a PBD solution that relies on a usage assumption known to fail in the past, fire services can require more significant reasoning as to why this particular building will succeed where many others have failed. This additional research would add more feedback in the design process and would proactively address the problem of buildings deviating from PBD usage requirements.

Actually performing this research is a more difficult task, especially given the small number of people available to gather information and the number of buildings involved. Fire services, as it is already involved in the research process, will likely play a large role in gathering this information. To get more people working on the problem, however, professional societies focusing on building and fire safety will be able to coordinate the research on a larger level and involve a greater number of engineers. The combined experience of many FSEs will allow for a wider breadth of research, and will carry more weight with decisions made based on the research.

13.2.2 Maintenance Contractor Evaluation

Another area of concern noted in many of the case studies and interviews was the use of contractors to perform fire safety system maintenance. Because of the technical nature of fire engineered systems, building managers are unable to verify the quality of the work performed by outsourced maintenance contractors. There is an existing solution that helps solve the lack of effective evaluation of maintenance work: making electronic copies of all maintenance logs and storing them in a database. The particular company operating this solution can then provide statistics to building owners concerning how much maintenance actually occurs in accordance with the schedule. This is information that building managers and owners would be

especially interested in, because they are paying for 100 percent of the maintenance contract, and only a small fraction of this maintenance may be scheduled. The interviewee (Subject 12) citing this system noted that in many cases the actual percentages of work completed was very low, but contractors quickly learned to be more thorough on the buildings using this system.

13.2.3 Increase Penalties

A more direct approach to forcing higher compliance with PBD requirement is to more aggressively fine building owners with noncompliant buildings. It has been noted by interview subjects that many building owners simply do not see the importance of maintaining buildings from a financial viewpoint. With a simple cost/benefit analysis, some building owners find that it is cheaper to leave problems unfixed, especially since they will not see the true benefit of an effective fire safety system unless there is a fire. The simplest fix to this problem is to increase fines for non-compliance, probably by at least an order of magnitude. Queensland currently implements an on-the-spot fine system, where fines can be issued on a per-infraction basis. For example, a fine could be issued for each fire door open, and at the rates used in Queensland, this would be \$1,875 per door (“Building Fire Safety”). Increasing enforcement like this would provide an additional technique to use, however it will not solve the problems of a lack of personnel to provide regular inspections. The city counsel could make an example of a building that was not well maintained. If this building owner could be fined a large sum of money for not being compliant, many other building owners could hear about the infractions and might ensure that their building is well maintained.

13.2.4 Improve Education

Another method of making properly maintaining a building for financially attractive is to educate building owners, managers, tenants and insurance companies about PBD and the liability involved in failing to meet the requirements specified by the FSE. For building owners, managers, and tenants, there is a need to highlight the level of liability owners face in the event that there is a fire and fire safety systems fail due to usage changes and maintenance shortfalls. Insurance companies should also be

more aware of the effect that additional fire engineering requirements can have on a building, and how breaking these requirements can make a building a financial risk. The intended effect of educating insurance companies is to make insurance premiums and policies more dependent on effective maintenance and correct usage of a building. This will add another level of financial pressure and usage enforcement onto building management.

13.2.5 Operating Manuals to Communicate Usage Requirements

Another, more important, area of education in the continued use and maintenance of buildings is educating building managers and owners about the specific requirements of their building. In case studies, it was apparent that some buildings had little to no documentation concerning how they should be maintained and operated. The best buildings, however, had clear documentation that could be implemented directly as policies. The most useful means of communicating the usage requirements came in the form of an operating manual. This was a set of documents provided by the builder and design team to describe how the building must be maintained and used. While the legal requirements for a building's use are listed on the occupancy permit and the essential services list, these were occasionally found to be unclear, especially to a non-technical manager. Occupancy permits frequently cite other documents, such as fire engineering reports or even the BCA, which means few people are able to extract the necessary information. A lengthier operating manual focuses on providing all the information necessary to maintain and run the building in a single document, explained in the form of policies that management can implement. This operating manual form of documentation was also cited by an FSE interview subject as currently in place in Singapore's new performance-based code, a policy that seems particularly effective.

13.2.6 Implement Self-Policing Policies

Another means of approaching control of usage is to encourage the use of self-policing policies. A self-policing policy is one that occupants will not break simply because breaking the rules is inconvenient or counter-productive. One example

would be stringing wire at the height requirement in a warehouse to prevent storage of goods above the limit, such as in the case of Building D. Another example commonly occurs in warehouses, in most cases unintentionally, where a very common requirement is to keep egress paths clear of debris. This was generally followed in commercial buildings, with a few exceptions. The characteristic these buildings had in common was the use of forklifts, which need open, clear space in which to operate. While the users were keeping the floor clear as a means of facilitating the needs of the forklift, they were also following a fire safety requirement. As a part of design, engineers should look for areas where usage constraints can be built into construction, by facilitating correct usage, and making incorrect usage inconvenient. For example, to keep building users from storing debris in the space underneath a fire stair, as was the case in Building B, the engineer could simply get rid of the space. One way to prevent fire doors from being chocked open is to add an annoying buzzer that goes off after the door has been open for over a minute. While these sorts of solutions may not exist for every usage requirement, they should be a goal during design.

13.2.7 FSEs Liable and Involved After Permit Is Issued

One of the major flaws with the building process itself is the lack of feedback in the system, as most building surveyors and FSEs are not involved with a building after permits have been issued. Combined with very limited liability on the part of the FSE, there is no method to ensure that the final building actually meets engineering requirements, and that those requirements are reasonable to begin with. Adding feedback to the design process could be approached several ways, with varying levels of procedural and legislative changes. Adding a more significant degree of legal liability on the effectiveness of the work of the FSE will provide an incentive to FSEs to verify the correct implementation of the fire safety system. An additional step in adding design feedback is to make granting occupancy permits conditional on a fire engineering inspection, with the name and signature of the design FSE appearing on the Occupancy Permit. This very prominent signature would highlight the fact that fire engineering occurred as a part of the design, and FSEs will be more likely to be careful in the design because their names are attached to the design. Not all of this change is simply to add more liability exposure to the FSE, it also provides a chance for the FSE to see how the design actually worked, and even enable changes before

signing the design off for occupancy. A requirement of this additional inspection should also include a requirement on the FSE to communicate the usage assumptions to the building owners and managers. This provides extra impetus on the FSE to ensure that building management understands the necessary usage requirements, and that the usage requirements are translated into policies that non-technical managers can implement and enforce.

13.2.8 Hire More Building Surveyors and Inspectors

One of the major issues underlying the problems found in this research project has been a lack of personnel, both at design time and during enforcement. There are a lack of building surveyors to thoroughly examine all the buildings that need approval, and a lack of fire services personnel and municipal building surveyors to inspect the buildings. The solution to this problem is to hire and train more building surveyors and inspectors. While this solution is relatively straightforward, actually attracting more people for these roles is a more difficult problem which is beyond the scope of this project. This project can, however, emphasize the importance of these understaffed roles, as these are the primary checks in the building process.

13.3 Closing Remarks

While these recommendations and conclusions are designed to apply primarily to the Victorian implementation of PBD, this research could be applied by other Australian states or even other countries. Because PBD is relatively new, research such as this project will be important to ensure that each PBD implementation successfully takes into account knowledge as to how accurate certain usage assumptions are. This will allow engineers and building surveyors to better communicate information to building managers, as well as identify commonly non-compliant usage requirements. Combined with additional research, a mix of proactive evaluation and reactive enforcement techniques will allow for a more robust program to prevent usage changes from reducing the effectiveness of fire safety solutions.

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Appendix A: MFB Description

The Metropolitan Fire Brigade (MFB) is an organization that provides several important services to the Melbourne community, including response to a wide variety of emergencies, as well as community education programs and fire safety engineering services to buildings under construction. The MFB is the umbrella organization that coordinates fire stations throughout the city.

A.1 MFB Background

The MFB's coverage area includes over 1,000 square kilometers, \$200 billion in assets, and over 3 million people. MFB provides a wide range of emergency as well as non-emergency services, including response to all types of fires, rescues, automobile accidents, as well as community educational services. There are over 1,700 emergency personnel spread over 47 fire stations throughout the city, providing emergency response 24 hours a day, often responding within eight minutes of a call. The non-emergency divisions of MFB provide several services, such as preparedness and awareness educational campaigns, advising city councils on issues related to fire safety, and acting as a statutory organization playing a role in the application of building codes. The MFB receives funding from several sources, including local and state agencies as a public service organization, as well as additional funding from outside stakeholders such as insurance companies. The MFB, however, is a non-profit organization (Metropolitan Fire Brigade).

The MFB has several internal divisions (see Table A-1). Below the CEO, 9 directors each lead a division. Two divisions are on the 'frontline' in delivering MFB's primary services: Operations oversees emergency response, and Community Safety oversees the educational and statutory programs. The remaining divisions are Corporate Strategy, Corporate Relations, Human Resources, Technical Resources, Finance & Administration, Corporate Governance, and Office of the CEO. The Community Safety Division is sponsoring this research project, and this project's liaison is Community Safety Technical Department Executive Manager Jarrod Edwards (Metropolitan Fire Brigade).

Chief Officer/ Chief Executive									
<i>Corporate Strategy</i>	<i>Operations</i>	<i>Community Service</i>	<i>Corporate Relations</i>	<i>Human Resources</i>	<i>Technical Services</i>	<i>Finance & Administration</i>	<i>Corporate Governance</i>	<i>Office of the CEO</i>	
Emergency Management	Central Zone	Community Education	Corporate Relations	Employee Relations	Equipment Development	Alarm Assessment	Corporate Compliance	Equity & Diversity Unit	
Equipment and Resource Management	Northern Zone	Community Education Technical Department - Jarrod Edwards	Media Production Services	Employee Services	Facility Services	Finance & Resource Budgeting	Records Management		
Operational Communications	Southern Zone			Dangerous Goods	Ethical Standards	Fleet Management Services	Financial Accounting	Risk Management	
Planning and Research	Western Zone			Structural Fire Safety	Health & Safety	Information & Comm. Service	Fire Equipment Services		
	Community Safety Liaison				Training & Education	Major Construction Projects	Statutory Contributions		
	Emergency Medical Response			Mechanical Engineering Services					
	Incident Management System				Supply				

Table A-1: MFB Organizational Chart (Source: MFB Organizational Chart)

The first volunteer emergency fire services in Melbourne were in the form of independent fire brigades, each funded by a different insurance company. The first known fire brigade was the Melbourne Fire Prevention Society which was formed in 1845. These groups were extremely competitive; it was common practice for the fire brigades to do their best to impede rival brigades' firefighting attempts. This changed after a series of destructive fires in 1889. In 1890 the Fire Brigades Act was passed, unifying the independent fire departments into the Melbourne Fire Brigade (MFB), which began operation on May 1, 1891 (Metropolitan Fire Brigade).

The MFB originally consisted of fifty-nine full-time firefighters, supplemented by 229 auxiliaries, four steam fire engines and twenty-five horse drawn carts. Over the years, the MFB has grown with the city of Melbourne. In 1889, the motto 'Audax et Promptus' was adopted, which is translated as 'Brave and Swift'. The organization also had to adapt to changing technology. By 1918, they were fully motorized with their own mechanical and electrical repair shops. In 1950 the MFB disbanded its volunteer branch in favor of a professional firefighting staff. By 1960 the Brigade employed 888 firefighters due to both the increasing size of Melbourne

and the forty hour work week. Throughout the 1970s and 80s the MFB expanded its fleet of vehicles, adding a group of vehicles designed for motor vehicle accident rescues and a variety of multipurpose vehicles (Metropolitan Fire Brigade).

With the increase in the availability of electronics the MFB began incorporating computers into its rescue operations. In October 1983 the Computer Aided Communications Centre was added, processing a majority of the Brigade's emergency calls. In 1984 the MFB began using a computerized hazardous chemical system called Detachem. The MFB made strides in gender equality in 1988 by employing its first female firefighters. Through the course of more than a century the MFB has evolved into the organization it is today (Metropolitan Fire Brigade).

A.2 MFB's Role in PBD

The MFB's role in the process of applying building codes is a complex one, due to the many parties involved. The person actually in charge of a building's certification for use and occupancy is the building surveyor, who acts on behalf of the town council. If the building uses a design that makes use of a design that is not covered under the Deemed-to-Satisfy requirements of the BCA, then the chief officer of the MFB must sign off on the safety of the design. In these cases, MFB engineers will evaluate the design to determine if it meets safety performance requirements, and make recommendations as to whether the design can proceed. The building surveyor is not required to involve the MFB if the building meets BCA Deemed-to-Satisfy requirements. After the building has been constructed, it has enforcement power limited to the fire appliances of the building (Barnett) (Edwards).

Appendix B: Interview Questions

B.1 Fire Safety Engineers

Information needed:

- The areas in PBD where issues may occur that may result in a building different from fire safety specifications.
- The effects of outside issues and constraints (such as design goals that require more safety, needs for particular types of building arrangement, specific cost goals, etc) on the design process and influence the choices made.
- How engineers help to pass information down to owners/maintenance/occupiers, and whether there have been attempts to measure the effectiveness.
- The engineer's opinion on the building code implementation in its present form.
- Opinions of the effectiveness of PBD (advantages, disadvantages, consequences).

Questions:

1. Communication:
 - a. How much communication between Fire Safety Engineers and building designers is there?
 - b. How much communication between FSEs and building owners and managers is there?
 - c. How are building owners/maintenance staff/occupants made aware of fire safety information and requirements?
 - d. Is there a way of verifying the level of awareness of the building occupants?
2. Design:
 - a. What sorts of assumptions are made as to the use of the building and where do they come from?
 - b. How are future changes in building usage taken into account in the design process?

- c. What are some of the constraints that show up from the designer/developer and how do they affect the design?
 - d. What sort of issues arise in finding a balance between cost and safety?
3. Regulatory Process:
- a. What are practical differences between an idealized build/regulatory process and the actual processes?
 - b. In practice, how thorough are approval processes in requiring thorough analysis of buildings?
 - c. Are enforcement officials knowledgeable enough to make good evaluations of buildings' safety?
4. General Opinions:
- a. In your opinion what are some of the advantages and disadvantages to PBD?
 - b. Are there any extra consequences (tradeoffs, changes in the way the process works) due to PBD? If so, please elaborate.

B.2 Owners, Managers and Maintenance Personnel

Information needed:

The amount of knowledge the occupants have of what their responsibilities are in maintaining the fire safety level in the building, specifically with regards to maintaining the accuracy of the assumptions made during design.

The amount of input owners have in the design process.

The general level of concern about fire safety issues among the occupants of a building.

General Purpose Questions:

1. Can you describe your job and some of the responsibilities it entails? How long have you worked here?
2. What sort of experience and training have you had related to your job?

Questions for Building Owners:

1. Can you describe the design process, specifically your role in it?
2. How much communication was there with the rest of the design team?
3. Do you feel that the final design met your objectives? If not, please explain.

Questions for Building Managers:

1. What sort of fire safety policies are currently implemented (Fire Marshals for evacuation, fire drills)?
2. How familiar are you with the design documentation for the building, specifically the parts that deal with maintenance requirements and the intended usage of the building?
3. Do you feel the usage assumptions made in the documentation match the actual current building usage? If not, please explain.
4. How aware are you of the effects of any discrepancies in building usage from the original design assumptions?
5. What sort of information have you been given on the critical assumptions made in the design of the building and what needs to be done to ensure they continue to remain accurate?
6. What sorts of fire safety programs have been implemented?

Questions for Maintenance Staff:

1. How familiar are you with the fire safety systems in the building such as sprinkler systems, smoke detectors, etc.?
2. What maintenance programs are in place for these systems?
3. How much concern do you have for fire safety as you go about your job?

B.3 Building Surveyors

Information needed:

- Any experience in practical implementation of building codes and opinions on the implementation as it stands now.
- Building Surveyor's role in design process.
- General opinions on PBD.

Questions:

1. How long have you been a building surveyor? What sort of background and experience do you have?
2. How involved are you in the design process for a building? How much input do you have?

3. How often do designers take advantage of alternate solutions? What are some common reasons for using alternate solutions as opposed to the deemed-to-satisfy conditions?
4. Do you feel that PBD results in safer buildings than if the deemed-to-satisfy conditions were used? Please explain.
5. How does the approval process work for a PBD? How thoroughly is the design checked? Is there any way to improve this process in your opinion?
6. How often are the surveyors called in to reevaluate the building? Is there a certain amount in the building that has to change in order for an inspection to take place?
7. What is your opinion of the building code implementation in place now? Does it generally result in safe buildings?
8. How often do buildings fail to satisfy the building code requirements? What are some common reasons for this?
9. What happens as the use of a building as it changes over time? Are there any systems in place to regulate this and mitigate any negative effects?

B.4 MFB

Information needed:

- Opinions on the building code implementation, specifically with regards to the Fire Brigade's role. Recommendations for improving the building code implementation.
- Opinions on how much building occupants know about what needs to be done to keep their building safe.

Questions:

1. What is your role in the MFB? How long have you worked here? What kind of background and experience do you have?
2. What kind of powers does the MFB have with regards to building code enforcement? How often does it use these powers?
3. How much do you think building occupants know about the assumptions made during design and how their actions can affect the fire safety level in the building?

4. Do you know of any instances where changes in building usage have occurred which invalidated the assumptions made during design? If so, please elaborate.
5. What do you think needs to be done to ensure that the design assumptions remain valid throughout the building's life time?

Appendix C: Case Studies

In order to maintain confidentiality, all identifying information has been removed from the building descriptions and site visit notes.

C.1 Building A

Description of the Buildings

Building Name (Letter)	Building Number	Levels Above Ground	Number of Units	Comments
A	1, 2, 3	6	40	Retail at Plaza Level
W	4, 5	4	33	-
P	6	9	60	-
K	7, 8	6	65	-
C	9	5	17	Retail on Ground Floor
B	10	8	-	Retail on Ground Floor
V	11	14	213	Retail on Plaza Level
M	12	2	3	Retail on Plaza Level

Only one building in the complex that will be examined, as it is the most complicated and has the largest amount of people in danger for a fire emergency situation. The building includes serviced apartments, retail stores on the Plaza level, and car park on the Basement floors. The apartments accommodate for one and two bedroom self contained boutique apartments. All apartments have king or twin bedding, separate bathroom, fully equipped kitchen, and separate living/dining area, reversed cycle air

conditioning, DVD player, private laundry facilities and balcony.

Primary Building

Stories – 14 above ground, with 4 below ground for car park

Age – 2-3 years⁵

Use – Residential Accommodations (apartments), Retail (on ground floor),
and

Car park (below ground levels)

Building Class – 2 (Living), 6 (Retail), and 7 (Car Park)

Height – 60.750 m

Construction – Construction Type A, Constructed of Masonry, steel beams
and columns, and new reinforced concrete.

Fire Safety Systems

Sprinkler System throughout entire building (car park, retail stores, and
apartments)

Exhaust System in the car park

Smoke Detection System throughout the entire building

Hoses, hydrants, extinguishers, booster, and signs

Automatic fire doors that close when smoke is detected

Smoke sealed doors

Alarm Systems

Signs indicating devices and exits

Special Constraints

All buildings obey the following rule:

“All apartments are to be documented and issue to each new tenant the
evacuation requirements and the emergency alarm requirements. This
is to be reissued to each apartment every 12 months. This document
encompasses straight forward information and instructions concerning
the nature of the alarm systems and the requirements of the occupants
in the event of a fire emergency.” Stated directly from PBD

⁵ All building ages are from the time this report was written

Deviations from DtS Conditions for Apartments

- Travel Distance to exit exceeds 6 m
- Stairs discharge within building
- Solid core doors not less than 35mm thick with self closers to apartments
- Replacement of EWIS with BOWS
- Single exit from plant room area > 100m²
- Floor Slab above the retail to have FRL of 90/90/90

Evacuation and egress

- Analysis done for people who are not aware of the fire before automatic detection due in part that they will be unaware of the fire before the alarms.
- Doors do have functional self closing mechanisms
- This analysis uses a door opened for 60 seconds which would be less likely to happen with self closing doors.
- The maximum travel distance in any building from an apartment is less than about 30m
- The Spread of smoke will be severe in the shorter corridor lengths because of the smaller volume of space into which it vents
- Premovement time of 4 minutes
- Travel Speed of 1 m/s for travel to stairs

Stairs Discharge in the building

- Only one fire occurs and more than one egress route will not be block
- Occupants using a stair for which egress is effectively blocked may return to the other stair for egress

The use of solid core doors

- Max fuel loads used for apartments: Living, Dining, and Bedrooms = 40 kg/m² wood equivalent, Kitchen = 15 – 20 kg/m², Bathroom = Neglected
- The fire totally consumes the fuel load

- For charring rates of about 0.6mm/minute, which are typical for medium density timber, the time to penetrate a 35mm solid core door may be determined as 58 minutes
- The worst credible situation, with sprinkler failure, would prevent fire spread and the door's integrity in 20 minutes, this is very conservative.

Replacement of EWIS with BOWS

- There will be no warden system to control or direct evacuation.
- *The occupants should be provided with information concerning the nature of the alarm in the building and their required action in the event of it being activated*
- Evacuation process should be completed before the fire brigade commences its activities. With minimal intervention from the MFB to help people get out of the building.

Provision of single exit from plant room

- The occupancy of people in the plant room are going to be people that are able bodies and people that are familiar with the building
- Small number of people in the plant room at one time so there won't be a queuing at the exits
- **No Specific analysis has been done for fires in Plant rooms**
- Electrical faults would most likely be the reason for fire in the plant room

Floor Slab protection from Retail to apartments

- If sprinklers are operating during a fire the slab will keep its integrity
- If an unlikely event of sprinklers not functioning the fire severity of a retail part may be estimated using a fire severity equivalence analysis
- Fuel load densities in retail shops are given as 600 MJ/m²
- *With glass areas of 20m in length and 2m high, if the glass were to break, the severities of about 30 – 45 minutes exists*
- If the glass remains intact, then the severity is about 90 minutes
- Both severities do not take into account the fire brigade intervention in which the fire brigade would be there in 20 – 30 minutes in most major cities

Deviations from the DtS conditions for the Car Park

- Deletion of stair pressurization to car park stairs over maximum of 4 levels
- Compartment exceeds 5000m²
- Discharge of stairs within plaza level lobbies of building

The Deletion of stair pressurization to car park

- Pressurization of the stairs is primarily concerned with the fire brigade's activities
- *The basement car parks are both sprinkler protected and provided with a smoke exhaust system*
- Sprinklers are regarded as a reliable means of controlling the spread of fire and consequently the volumes of smoke produced
- *The exhaust systems provide enough ventilation with no volumes of smoke leaving the through the ramp, in the case of a car fire*

Compartment exceeds 5000m²

- The chances of a fire spreading in a sprinkler protected car park is very low
- Based on the same test/analysis proving that the deletion of the stair pressurization satisfied the performance-based requirement
- The Sprinklers provide effective compartmentation as is equivalent to a smaller size car park

Discharge of Stairs from car park to plaza level

- The major concern for this solution is when the fire is at egress level or the fire will block off the egress route
- There are alternative egress routes
- The assumption is that there will only be on fire at the time of the accident, which will always leave one egress route open
- This building has two stairs which provide alternative egress routes to the outside
- Occupants that find that the first egress route is blocked can then proceed to return to the other stair for egress

Visit Check List

Apartments and Retail

1. Doors closed to apartments are closed
2. Doors to stairway are closed
3. Doors have functioning self closing devices
4. Doors are properly sealed
5. Maximum distance to stairs is less than 30 meters for egress
6. Shorter time of egress for shorter corridors
7. The right size doors (thickness)
8. Rooms, lift lobbies, or hallways aren't filled with excess amounts of fuel
9. The occupants (Short-term and long term) have the required information concerning the nature of the alarm in the building and their required action in the event of it being activated (not in serviced apartments):
 - Check to see if they received the information upon moving in (Short-term and Long-term Tenants)
 - Check to see if they receive the information every 12 months (Long-term Tenants)
10. Postings for maximum occupancy for plant room
11. Sprinklers aren't shut off or isolated
12. There aren't any isolations or faults in the fire alarms, checked through the fire brigade's instrument panel in the fire control room
13. Glass windows are cracked or broken in retail stores
14. Egress routes are indicated throughout building

Car Park

1. Doors to car park are closed
2. Sprinklers aren't shut off or isolated
3. Exhaust system is running

4. Sprinklers aren't damaged or broken
5. Signs indicating all egress routes

Questions to ask Managers/Owners

1. Have you given the occupants their evacuation information?
2. Have you continued to give it to the occupants every 12 months?
3. Are there any procedures that you perform to check on the fire safety systems so they still are in working order?
4. Do you have a log of any maintenance done on the fire safety systems?
5. Do all the tenants (short-term and long-term) get the evacuation procedure?
6. What do you consider a short-term resident?

Site Visit Notes

Apartments and Retail

1. The tenants of the apartment did have their doors shut and were not propped open. It seems that the people wanted to keep their doors shut just due to privacy issues. Inherently, they keep themselves safe in this process. The self closing mechanisms helped in keeping the doors closed.
2. The doors to the stairway were closed at all times. When opening the doors, sometimes the doors would not shut due to the wind or suction in the stairway. This could be a problem when trying to keep the doors closed for the pressurization to stay effective, but the doors were monitored and they knew to check to make sure that the doors were adjusted if they were not shutting properly. The self closing mechanisms helped in keeping the doors closed.
3. As referred to in the last two conclusions, all the doors do have the self closing devices and they are functioning properly. They are also monitored to make sure the devices are functioning properly that way if there is a problem it will be fixed in a very timely fashion.
4. All the doors were properly sealed that includes both the doors into the apartment as well as the doors into the stairway.

5. On the floors with longer egress routes, the distance was checked to see if it complied with the fire engineering report. The distance was check and also this path clear of any debris. Any rubbish or trash that was in the path would have inhibited people to get to the stairway. Actually there was no debris found in those hallways or in any hallways and the distance was compliant with the report.
6. The hallways were all pretty much the same width and same height so the need for shorter egress time for narrower corridors was not prominent.
7. The doors were all in order. The thickness was correct and they did use the same doors through out the entire building. Also the doors were solid core therefore ensuring that they were the right fire rating.
8. In this building the hallways, stairways, lobbies, and lift lobbies were all clean and clear of trash. The trash chute room was not filled with trash either ensuring that people would be able to easily get rid of the rubbish they had. Like stated earlier, all the hallways were clear which helps for the egress. Both stairways were clear of trash and the lobby at the main entrance had no excess fuel that would cause any concern for safety.
9. All of the occupants are given the evacuation procedure, short term and long term, and are required to read and also it is also posted on the back of the door that leads to the hallway from the apartment. The thing that made these evacuation procedures even better than normal is that they hand make all of the evacuation procedures for each individual apartment. They feel by doing this that there is no confusion for what to do in the case of an emergency. They are given this procedure when they move in and if they are living in the same place for a year or more than they will receive updates to their evacuation plan. At the time of the visit there was actually a problem with the facility, but it made it so the people from the 7th floor to the 13th were not able to evacuate the building. This would be a problem, but the manager of the building had informed everyone on those floors of the situation and also informed them what to do in an emergency situation. This one on of the first things that we learned about upon talking to the manager. This just showed how involved and understanding the manager is with the building. This satisfies the replacement of EWIS with BOWS since it is managed correctly.

10. The team was not able to get up to the plant room during the visit, but the owner was questioned about it. The plant room was not accessible to the people in the building so there is no way that the plant room would be over crowded at any point. Therefore, there was no necessity for a maximum occupancy sign to be posted. This also shows that the need for a larger exit door would not have been necessary as discussed in the FER.
11. In this building there were sprinklers that were isolated at the time of the visit. The manager informed the group and the inspector upon meeting with him. He was very knowledgeable about the situation and was following the necessary precautions in this type of situation. As discussed in the conclusion number nine, there were isolations from the 7th floor to the 13th floor and the manager informed the occupants of the situation. The inspector was very pleased to see and hear that the correct precautions were being followed. The fault was found from the bi-yearly check that the manager performs and he was following procedures to fix the problem as soon as possible. It was also noted that the Pump Room and the Fire Control Room were clean and clear of extra fuel and obstructions. The Pump Room was properly sealed from any penetrations. The Fire Control Room was wide open and also very organized giving the fire brigade plenty of room if they were to come into the room in the case of an emergency. The one thing that the MFB inspector did notice that the log was not kept in the Fire Control Room or the Pump Room because it was in the manager's office. The inspector suggested that the manager put a sign in both rooms to let emergency personnel know that when they arrive in an emergency. The manager right away wrote it down and said he will put up the sign right away.
12. In the Retail Stores on the plaza level, all the windows were in good condition. This is important to prevent and fire spread. None of the windows were cracked or broken and this will ensure a good FRL.
13. The exits were all clearly indicated and all the signs were fully functional. The manager uses a program that monitors all the lit exit signs so when it is time to check the signs, the manager starts the program before he leaves one night and then by the time he comes in the next morning the document is on his computer. This document indicates all the lights in the building that are

functioning or not functioning. The manager then has all the ones that must be fixed, repaired or replaced.

Car Park

1. In the car park, all the doors leading into the building were shut and using the similar closing devices that the apartments used. These doors were all functioning, but they were also monitored. The doors into the fire control room and the pump room were also closed and locked so no one that isn't suppose to be in the room was kept out.
2. In the car park none of the sprinklers were isolated or turned off. There was one concern from our advisor who had seen the car park earlier that week and that concern was that the sprinklers couldn't handle the load of the storage cages that were overfilled. Upon further review of the fire engineering report, there was nothing in the report that indicated that this was much of a problem.
3. The Exhaust system was running which prevented any collection of fumes from the cars. This system, in the case of a fire, is strong enough to discharge the smoke from the car park with out any volumes of smoke leaving through the ramp.
4. All the sprinklers that were searched were all in good condition. None of the sprinkler guards were on them either. The only concern was that the sprinklers in the storage area were unable to contain a fire if a fire were to start in a storage cell. However, as said before, the fire engineering report did not specify that any provisions had to be taken into consideration.
5. As explained in number 13 of the conclusions for the apartment section, all of the exit signs were clearly indicated and all were fully functional. These exit signs were also monitored by the same program indicated in conclusion number 13.

C.2 Building B

General Building Description:

- Age: 3 Years

- Height: 26.8 m
- Stories: 9
- Construction: Type A, primarily reinforced concrete floors, precast load bearing and non load bearing, light weight walls and masonry with an FRL of 90/90/90.
- Use:
 - Ground Floor: Carpark (six cars), Foyer, Retail (Class 6)
 - Levels 1-9: Residential Apartments (Class 2)
- Occupancy: 80 apartments, ~252 occupants (number used for RSET calculations)
- Special Features: Single stair, 2 stage alarm system (2 smoke detectors in lift lobbies; upon activation of one, smoke doors close and pressurizations system activates; upon activation of second, MFB is automatically called to scene)

Fire Safety Systems:

- Fire hydrants on all levels
- Automatic sprinkler system covering entire building
- Fire pumps for hydrants and sprinklers
- Booster connections for hydrants and sprinklers
- Brigade fire alarm connection
- Stair pressurization
- Portable fire extinguishers
- Smoke detection in common areas
- Smoke alarms in apartments
- Emergency lift and stretcher facilities
- Emergency lighting and signage
- Emergency Warning System
- Apartment walls have FRL of at least 60 minutes
- Solid core apartment doors with smoke seals

Deviations From Deemed to Satisfy Provisions:

- Unprotected openings of building closer than 3m to property boundary on West, East and North sides
- Single fire isolated stair through entire height of building discharging to street
- Deletion of Warden Intercommunication Points (WIPs)
- Grade II Water Supply instead of Grade I
- Construction FRL of 90/90/90 instead of 180/180/180 required for Type A Construction
- Solid core doors for apartments instead of fire doors

Usage Assumptions Used for Alternate Solution:

Unprotected openings of building closer than 3m to property boundary on West, East and North sides:

- No usage assumptions made (reliant on design features such as wall-wetting sprinklers)

Single fire isolated stair through entire height of building discharging to street:

- Stairs will be pressurized to maintain tenable conditions
- Compartmentalization critical to maintain tenable conditions in egress route
 - Doors to stairway must be kept closed
 - Doors to apartments should be kept closed (FEB indicates that with apartment doors open untenable conditions will occur in corridor prior to RSET but that sprinklers will then activate and make corridor tenable again. No analytical evidence provided to support this)
 - Penetrations between compartments should be sealed or enclosed to prevent spread of smoke, fire, etc.
 - Egress paths (Corridors, lift lobby, stairway, etc.) must be kept clear of combustible materials

Deletion of WIPs:

- Because of transient nature of occupants, not likely that residents will be given Fire Warden responsibility
- Emergency Management Procedures will be prepared and occupants made aware of what to do in an emergency

Grade II Water Supply instead of Grade I:

- No usage assumptions made (redundancy that would be provided by Grade I water supply replaced with redundancy of fire protection measures in building)

Construction FRL of 90/90/90 instead of 180/180/180 required for Type A Construction:

- Excessive fuel loads in retail area (assumed to be maximum of 1300 MJ/m² for news stand) or electrical switchboard room (assumed to be maximum of 300MJ/m² for cable) could invalidate these calculations; this will be done by estimating the weight of the fuel in each area.

Solid core doors for apartments instead of fire doors:

- No usage assumptions made (combination of automatic sprinklers and self closing, smoke sealing, solid core doors will maintain tenable conditions outside Room of Fire Origin (ROFO) long enough for occupants to safely evacuate)

In general, assumption made that sprinklers will be unobstructed and no point on floor will be further than 3m from a sprinkler

Assumption made that sprinklers will contain any fire to room of origin

Fire Safety Policies:

- Minimize unnecessary combustible loads
- Regular housekeeping
- Ensure clear and accessible exit paths
- Ensure fire and smoke doors closed
- Periodic inspection, testing, and maintenance of all fire safety systems should be performed. No further details are provided.

Specific Questions for Building Owner/Manager:

- What kind of maintenance is performed on fire safety systems (sprinklers, pressurization system, etc.) and how often is this done? Are records kept for this maintenance and do you have it available for us to see?
- Have emergency procedures been prepared and distributed to tenants?

Additionally, we will need information on the existence, or lack thereof, of the fire safety policies specified in the FEB

Visit Checklist:

1. Stairway doors closed
2. Stairway clear of obstructions
3. Stairway clear of combustible material
4. Lift Lobbies clear of obstructions
5. Lift Lobbies clear of combustible material
6. Corridors clear of obstructions
7. Corridors clear of combustible material
8. No penetrations between compartments
9. Residents aware of emergency procedures
10. Fuel loads similar to those used in analysis
 - 1300 MJ/m² for retail (estimate dimensions and weight)

- 300 MJ/m² for switchboard room (estimate dimensions and weight)
- Ceramic Tiles/Stone floors in egress route
- Plaster Walls in egress route

11. Apartment doors closed

12. Fire safety systems functional (as best can be determined on visit)

- Smoke doors
- Sprinklers
- Pressurization system
- Fire detection
- Alarm systems
- Exit signage
- Emergency lighting
- Fire extinguishers
- Fire Hydrants
- Fire Pumps
- Boosters

Site Visit Notes

After obtaining a master key, the team entered the lobby and observed that the fire extinguisher closet contained a mop and bucket instead of a fire extinguisher. The team then went to the top floor and worked its way down. The specific details for each floor are noted below.

The most common flaw was with the fire extinguishers. These were missing in several areas and the ones that were present were not maintained properly. In general the corridors were kept clear of debris and combustibles. It was also observed that many of the lighted emergency exit signs were not working properly.

On the second floor, the team went inside a room that was being cleaned. The room did not seem to be occupied and was observed to meet the requirements for smoke

detectors, sprinklers, etc., although it was noticed that there were no floor plans or evacuation procedures in the apartment.

All the doors to the stairway were closed and the stairway itself was for the most part clear of debris. At the bottom of the stairway, however, there was a significant amount of furniture, washing machines, and other debris. In the sprinkler and hydrant pump room there were several penetrations for ducts which were not sealed. The maintenance records also indicated that for a long period of time the sprinkler running warning light had not been working, which means the pump could be running without anybody knowing about it and eventually burn itself out.

The exit to the street was blocked by several rubbish bins and a dumpster. The door still opened and the bins could be pushed out of the way if needed but it would still provide impedance to evacuees. In the mailbox area of the lobby approximately 40-50 phonebooks and other paper/cardboard debris was found. The mailboxes also would likely obstruct the flow of water from the sprinklers to these objects.

It was not possible to get into the switchboard as it was locked, but the retail area, which was assumed to be the office area, seemed to have a relatively light fuel load.

- Lobby
 - No fire extinguishers in either marked fire extinguisher cabinet (one had mop, another had painting supplies)
 - Stacks of phone books in mail area, obstructions in the way of sprinklers
- Floor 9
 - No fire extinguisher near sign
 - Large gap at bottom of door
- Floor 8
 - Fire Extinguisher not maintained – March 05
- Floor 7
 - Fire Extinguisher not maintained – March 05

- Floor 6
 - Smoke seals
 - Cabinet doors unlocked
- Floor 5
 - Fire Extinguisher not maintained – March 05
 - Small trash bag in hall – how is trash handled?
- Floor 4
 - Fire Extinguisher not maintained – March 05
- Floor 3
 - Fire Extinguisher not maintained – March 05
- Floor 2
 - Fire Extinguisher not maintained – March 05
- Individual Unit
 - No marked evacuation instructions, map on door-how are emergency procedures distributed, if at all?
- Floor 1
 - Fire Extinguisher not maintained – March 05
 - Lit exit sign doesn't work on AC
- Stair
 - Don't appear to be wider than usual
 - Washing machines, refrigerators, and other debris in bottom of stair
 - Hydrants not maintained
 - Many of the emergency lights don't test properly
- Basement
 - Propped door to store room, however little fuel
 - Pump room
 - Sprinkler logs indicate a reoccurring problem with the indicators on the pumps – could result in pumps running excessively and burning out the motors.
 - Open penetrations in walls near ducts
 - Rear Exit has trash bins and a dumpster very close to the door, would move trash bins to escape
- Office

- Pictures to determine fuel load – small area visible in office
- Protective cap on one sprinkler

C.3 Building C

Age: Still under construction, opened for staged occupancy in December 2006

Description: The building is a 36 story residential apartment building with a carpark from the basement to the 6th floor shared with an adjoining apartment tower on the same property. Basement includes an Avis rent-a-car business (with exposed 10,000 gallon petrol tank in the carpark), and at ground level there is an Aldi grocery store. The building is a single-stair design, with a central core to the building containing three elevators, a lift lobby, a storage and garbage chute room connected to the lobby, and a pressurized stairwell through the length of the tower. There is a 4th lift that runs through only the carpark levels. The lift lobby is separated by smoke doors with magnetic door release systems, and they are meant to separate the corridor from lift lobby should smoke detectors trigger.

Special Circumstances: The building used staged occupancy to allow for occupants and builders at the same time. During this time, there are two of the three main lifts open for use, and only floors 8-25 were under occupancy, with ongoing construction on the above floors. The 6th floor carpark level was being used as a staging area for the construction, rather than for parking cars.

Fire Safety Systems:

Stair Pressurization System – keeps smoke from spreading into the single stair

Automatic Sprinkler System

Smoke Detection/Smoke Doors – doors separate corridor from lift lobby when detectors activate.

Occupants:

Residents: Those living in apartments.

Note: This building was observed over a longer period of time because it was the housing for the team and advisors. This allowed frequent observations to be made of the building itself, as well as further observations on the process of making changes to the building's systems to force compliance with performance requirements. The main aspect influencing the implementation was the presence of builders during construction. The flaws found in the implementation changed over time, and the description here includes a timeline to show the effect of these changes.

Site Visit Notes

Initial Flaws in Implementation:

1. Virtually all of the stairway doors from the first through the 36th floor were open during the day when the builders were in the building. After about 4:30 PM most of these doors were closed, but approximately twenty remained in the open position. This included the doors on the third, fourth and sixth car park levels. All doors are marked "DO NOT PROP OPEN"
2. None of the communication cable closets in the exit access corridors on the residential floors were locked shut. As a result a fire in this space threatens the egress path. In addition, because wires are still being pulled throughout the building, there was no fire stopping between floors within these closets.
3. About half of the garbage chute closet doors were chocked open.
4. Many exit signs to the one exit stair were not installed; this is especially true above the twentieth floor. Exit signs were lacking or inadequate (in numbers and location) on most levels of the car park.
5. Fire stopping within the exit stairs was lacking.
6. Gaskets between the lift lobby smoke doors were missing on most floors.
7. Not all of the door latches to the exit stair were functioning.
8. Many of the doors between the lift lobby and the car park lack closers or adequate latching mechanisms with the ability to close doors completely.
9. There was a 45 kg (100 lb) cylinder of Liquefied Petroleum Gas (LPG) in the 6th floor lift lobby. The door to the car park on this floor was chocked open,

as was the door to the exit stair. In addition to the LPG, rolls of construction material were also present in the lift lobby.

Timeline for fixing implementation issues:

As a result of these issues, a formal complaint with the MFB was filed late in the afternoon of the 9th of March. Due to the lateness of the day, the MFB was unable to inspect the building until the next working day, the 13th of March. However, contact was made with the fire safety engineer who had designed the building and the building inspector for the City of Melbourne. The fire safety engineer stated that his design had not anticipated a phased occupancy of the building and that he was unaware of the current situation. At this point, there was nothing else that could be done that day by the MFB.

Additional Flaws found in MFB Inspection:

10. No fire extinguishers to compensate for lack of hose reels on floors
11. Garbage chute rooms lack fire extinguishers (signs exist for mounting brackets)
12. Fire control room has no signage, and also stores cleaning supplies.
13. Holes in doorjamb could result in airflow even if doors are closed.

Due to this delay, the original complainant returned to the building and closed any open stairway and lift lobby doors and moved the LPG from the 6th floor lift lobby to an area just outside the lift lobby door in the carpark (on this floor this is the portion of the car park used by the builder to store construction materials), and secured the door to the lift lobby and exit stair on this floor.

On the 13th of March the MFB inspected the building. A report was written by the MFB and hand delivered to the City of Melbourne Municipal Building Surveyor. The complainant continued to observe all of the items listed above, except for item 9 as the LPG was still in the location on the 6th floor where he had moved it on the previous Friday. During the day of the 15th of March the building manager notified the MFB that the LPG had been removed.

On the evening of the 15th of March, the complainant walked through the building, as he had every day he'd been in the building. Most of the issues listed above were still a problem. He wrote the MFB that evening with a report of his observations.

On Friday, the 16th of March, the complainant learned from the company WPI rents the apartments from that the building owner and management team had been notified by the City of Melbourne about the fire safety issues and was fixing them. In particular, the stairway doors would no longer be left open and the LPG tank had already been removed. That night he found most of the stairway doors were closed, but the doors to the car park were still open. This included the doors on the 6th floor where the LPG tank was still present.

On the morning of the 17th of March at about 10 AM, the complainant walked down the stairs closing many stairway doors, which the builder had chocked open that morning.

On the evening of the 17th of March, the complainant closed the doors between the lift lobby and the car park on the 6th floor and observed that the LPG tank was still present.

On Monday morning, the 19th of March, the builder and the owner had a meeting where a representative of the company WPI rents the apartments from was present. At this meeting they discussed the fire safety issues. At that time they apparently issued strict orders to keep the stairway doors closed. They denied that the LPG tank was present.

At about 4 PM on the 19th of March, the complainant called Worksafe Australia and filed a complaint about the LPG in his capacity as a site visitor. This was on the advice of the MFB who stated that they had no jurisdiction over the LPG tank. Worksafe assured that an inspector would visit the building on Tuesday the 20th of March. Such an inspection did take place and by 6 PM that evening, the LPG tank was no longer near the lift lobby of the 6th floor. That evening, one of the workers for the builder was observed going through the building checking for open doors and was apparently securing any doors that were open. At 11 PM that evening the

complainant walked down the exit stair from the 23rd floor to the ground level and found all of the doors closed, although two were not properly latched. The doors to the lift lobby on the 4th and 6th floors were open and he closed them.

On the morning of the 21st of March, the complainant observed that the stairway doors were closed. However, the latch mechanisms were disabled by being taped open. He notified the MFB of this and enquired as to whether the stairway smoke pressurization system had been commissioned.

Additional Flaws (21 March):

14. Door latches defeated through the use of duct tape.
15. Large volumes of construction debris on the first floor carpark and lift lobby, doors chocked open. Note: This area has no sprinklers.
16. Trash container in stair
17. Dust cap on lift lobby smoke detector

Additional Flaws (22 March):

18. Latches jammed open with screws and nails to prevent doors from latching properly.

Changes (23 March):

Doors now unlocked and kept latched for the most part rather than chocked open or with defeated latching mechanisms.

Additional Flaws (27 March):

On Tuesday evening, outside of the gym there was a 45kg LPG that was unprotected and unsecured. This LPG was placed outside of the secondary entrance/exit to the workout facilities no more than 2 m away from the glass windows underneath the awning.

Management Response Notes:

During the initial meeting with the building manager with an MFB inspector, the manager was very quick to be helpful to the inspector in finding problems, and trying to find ways of fixing the problems, specifically after being

shown photos of implementation flaws. It did appear that the manager was at least unsurprised at the existence of the flaws. At this time the manager promised that existing security staff would immediately start checking for open doors and such things as the LPG tank would disappear. In the days that followed, little actually changed, however.

There appeared to be a disconnect between the builders and the management in terms of communication, because any new orders from the managers didn't actually make it to the builders. The communication in the other direction was a problem as well, as management reported that the LPG tank was removed when it was still there, and also suggested that it was air conditioning fluid (photographic evidence indicates otherwise). This indicates either significant gaps in communication or a certain level of deception (possibly a mix).

Only after significant work, including notices from the City Council, Worksafe Australia (Australia's occupational health and safety organization), and from MFB, did any changes really start to occur in the building. The builders, in particular, were behind many of the problems, and not only did it take too long to force changes, they found new ways of keeping doors from closing when the door chocks were removed. This is a particularly bad area of communication, as there are signs on all the doors that clearly state "DO NOT PROP OPEN," and the builders still kept the doors open after being told several times not to close the doors.

C.4 Building D

General Building Description:

- Age: 2 Years
- Height: 7.8 m
- Stories: 1
- Floor Area: 7,550 m²
- Volume: 58,890 m³

- Construction: Defined as Type C, in actuality mostly type A, 150mm thick precast concrete panels with FRL of 180/180/180.
- Use: Storage of large rolls of paper (Class 7b)
- Occupancy: employees, >30 for a given shift

Fire Safety Systems:

- Smoke Detection and Alarm System
- Fire Hydrant System
- Hose Reels
- Drenchers in Canopy
- Concrete Walls have FRL of 180/180/180
- Emergency and Exit Lighting

Deviations from Deemed to Satisfy Provisions:

- Deletion of sprinkler system despite storage height greater than 4m
- <18 m clear space surrounding building
 - 7 m clear space on southern boundary
 - 11 m between new and existing building with canopy located in between
- Construction of steel framed roofed canopy over 6m vehicular access path between buildings
- Ignore the interconnection of the two buildings via the canopy on hydrant system demand

Usage Assumptions Used for Alternate Solution:

- Rolls stacked no more than 4 high (5.2 m)
- Rolls tightly wound and bound by steel bands
- <100mm separation between rolls
- Lightweight and Medium weight paper (no tissue paper)
- Bulk storage less than 4 m

- Low occupant density
- Security guards present 24 hours a day
- Occupants trained in fire safety
- Emergency plans prepared and practiced
- Emergency plans posted including:
 - Location of exits
 - Location of extinguishers
 - Location of assembly reels
 - Procedures
- Maximum travel distance of 40m
- No combustibles stored under canopy

Visit Checklist:

1. Rolls stacked less than 4 high
2. <100mm separation between rolls
3. Rolls tightly wound (i.e. no used rolls)
4. Steel binding around rolls
5. Rolls consist of lightweight or medium weight paper only
6. Other materials stored less than 4m high
7. Travel distance no more than 40 m
8. Emergency plans posted
9. Staff properly trained (likely will need to ask manager to determine this)
10. Building occupied 24-7 (likely will need to ask manager to determine this)

Questions for Building Owner/Manager:

- What sort of emergency procedures are in place? How often do you practice them?
- How many people are here at any given time? Is there somebody here at all times?
- What policies do you have in place concerning the storage of goods in the warehouse?

Site Visit Notes

Site Visit Notes:

The team visited the site with an inspector from the MFB. The team was accompanied initially by the chief engineer for the building and later joined by the factory manager, who had more knowledge about some of the policies in place. The primary focus of the site visit was the new warehouse that had been added to store paper for use in the neighboring manufacturing area. During the documentation review, a canopy joining the two buildings was also identified as an area of concern but it was discovered upon arrival that this feature had been omitted due to pressure from the MFB.

The warehouse was found overall to be clean and well maintained. The rolls of paper were stored in clearly defined areas and were all new, tightly bound rolls as the design specified. One critical requirement specified in the design was that paper rolls were not to be stacked any higher than 4.8 meters. There were policies in place for this, with signs posted at the correct height. The number of each type of rolls that could be stacked under this height had also been calculated. For the most part these restrictions were followed. There were a few areas where the rolls were stacked to an approximate height of 5.2 meters. This was brought to the attention of the factory manager who promised to fix the problem.

The other major requirement was that paper be stacked as close together as possible, with maximum separation between rolls being 100mm. This was found to be true within each grouping or row of paper although there was some question as to the separation needed between each single row of paper. This was found in many areas to be more than 100mm. When the manager was questioned about storage policies, it was found that there were no set policies on distance between rolls, other than that they had to be within the lanes painted on the floor. They were stacked closely together simply because it was more economical, not necessarily because of fire safety.

The rest of the building was largely found to be compliant. All the extinguishers, hose reels, and exits were clearly marked and had been recently maintained. The MFB inspector did raise the issue that the manager had not been completing the annual essential safety measures report and that this could result in large fines. The manager agreed to do the report and the MFB intends to return in a month to perform an audit.

The occupancy permit for the warehouse was particularly interesting. Not only was it clearly displayed in the warehouse, it was also much more detailed than other occupancy permits the team has seen. Instead of referring to other documents, the permit clearly listed all the essential safety measures and the requirements for each, in addition to identifying the alternative solutions used in the building and the requirements for those.

Issues:

- Storage of paper rolls
 - Design specified that paper rolls be stored under 4.8 m and less than 100mm
 - **Flaw:** Some areas had rolls stacked as high as 5.2 m
 - **Flaw:** Some rolls were separated by more than 100mm

- Maintenance of essential safety measures
 - Annual essential safety measures reports were not being completed

C.5 Building E

Description of the Buildings

The Building was extended from its original floor area 16,670m² to 18,730m².

This is therefore considered to be a large isolated building.

Floor to Ceiling Height: 8.5m

Number Buildings	Single large isolated building
Rise in stories, number of levels	Rise in stories of 1. Single level
Classes of use	Class 8 Distribution Centre Class 5 Offices
Floor Area and Volume	Following the Extension: Approximately 18,730 m ² And Approximately 108,000 m ³
Type of Construction	Type C
Type of Structure	Steel Portal frame with 5 degree roof pitch. 7m Springing height with 10m apex approximately
Fire and smoke compartmentation	No fire and smoke compartmentation in building. Office separated from DC by precast concrete walls containing windows and doors
Number of exits	Exits distributed around perimeter of building to achieve DTS compliant travel distances in original building as well as the newer extension.
Boundary distances	>18m to side and rear boundaries Generally >18m between buildings on the same site, except for conveyor connecting buildings at high level.

Fire Safety Systems, Active Systems, and Non-active Systems

- No Sprinkler System
- No fire detection system

- Internal communication system with each “team leader”, present at each bay in the main building, having a mobile phone to contact the permanently manned security gatehouse. Security would then activate the alarm which is heard through the PA system.
- CCTV system connected to gatehouse, occupied 24/7
- DTS compliant fire hose reels, plus fire extinguisher at each exit door
- No smoke ventilation system. Natural smoke venting system comprising a permanently open 300mm wide clear ridge vent along full length of apex, and large number of readily openable roller doors to sides of building.
- Non-compliant perimeter access, due to awning in the North West (existing) part of building.
- DTS compliant fire hydrants, on main with booster, including ground balls subject to previous MFB report and consent.
- New MFB report and consent required for ground ball serving new extension
- Multiple Exits
- Direct access to the outside due to the workers being clustered around the roller doors when loading and unloading the trucks
- Occupants can sense fire themselves
- Alarms can be raised by direct communication and by the occupant warning system/ PA system
- Occupants can suppress the fire by the hose reels and extinguishers and/or they can have fire fighter intervention upon arrival by the brigade
- Fire wardens will assist with evacuation in their area
- Fire Hose Reels
- Fire Extinguishers
- Fire Hydrants
- Emergency Vehicular access
- Smoke exhaust system – two fans 15m³/s can be used to exhaust smoke

Occupant Characterization

Use	Floor Area (approx), m²	Number of persons accommodated
Class 8, internal space	15,210	507
Class 8, west awning	1,520	51
Class 5 offices	2,000	200
Total	18,730	758

Special Constraints

- No Packages are stored in the building overnight. Goods arrive by truck in the morning and to be unloaded and automatically sorted. Goods are unloaded from large trucks by forklift, to be de-palletized within the terminal building. Conveyors transport the cartons automatically to the dispatch side of the terminal where they are stacked on the floor ready for loading onto trucks.
- The centre of the building accommodates the automatic conveyor system including high level platforms and conveyors.
- Smaller trucks and vans enter the building to load and unload. The larger trucks reverse up to large roller doors which constitute the majority of the external walls of the building.
- Ignoring the possibility of system failure

Potential fire hazards

- A truck or van fire within the building
- A forklift truck fire
- A fire in the equipment leading to a carton fire
- A fire may occur in a group of pallets, or in a linear row of pallets or stacked cartons

Assumptions

Any changes to the building design or use may mean that the assumptions are not valid, in which case the implications are to be reviewed

by a suitably qualified Fire Safety Engineer and /or Building Surveyor. The conclusions of this report may not be valid if the assumptions are incorrect.

- All fire safety aspects of the development which are not addressed within this report comply with the DTS provisions of the BCA, unless otherwise noted.
- The assessment and analysis are based on the assumptions that the development is complete and operational.
- All fire safety systems and management strategies will be maintained in accordance with this report and the relevant Building Regulations and Australian Standards.
- Any significant changes to the design drawings and/or specifications will be referred to the relevant Building Surveyor and/or Fire Safety Engineer for review prior to acceptance.
- All the occupants are alert and awake
- With the type of work that goes on in the facility, it is assumed that everyone that works in the building can move at a pace of 1.2m/s

Deviations from DTS Conditions

1. Building has no Sprinkler System
2. Building has no compliant smoke-and-heat vent or full smoke exhaust system
3. Providing External hydrant access
4. To permit hydrant shortfall in the building
5. To permit hose reel shortfall of coverage in the building
6. To permit emergency vehicle access into the open space around the building.

Visit Check List

1. Check the egress paths to make sure they are clear from obstructions
2. Check for painted lines in the fire hydrant areas to keep trucks from parking there

3. There isn't any oil/gas spills from trucks or fork lifts that could cause ignition
4. Check for Fire extinguishers and make sure they are in indicated areas that has a shortage of hose reel reach
5. Check for hose reel coverage to office area
6. Check for adequate fire alarms are placed near exits and around the building
7. Check for any broken fire alarm operators
8. Make sure no packages stay over night
9. Check for any broken roller doors
10. Check to see if they have a log for their essential safety measures
11. Check to see if they conduct their emergency warning PA system (suppose to be check on the first Monday of every month at 7AM, 11:30AM, and 5 PM
12. Are the Fire alarms clearly marked
13. Are the Exits clearly marked

Questions to ask Managers/Owners

1. Do you store any packages overnight, or is there an overnight storage area
2. Do your workers know how the fire wardens are in their areas
3. Are the workers aware of the fire extinguishers (there whereabouts)
4. Are there any handicap workers or anyone that may be physically deficient
5. Are the workers aware that the hose reels may not reach certain areas of the building
6. Are you using the building for anything other than a package distribution building
7. Do you have security guards ... How many
8. Have you ever had a fire, big or small
9. If so did you not call the fire brigade
10. Did the employees put it out

Site Visit Notes

Visit Description:

The team, accompanied by two MFB inspectors, arrived at the front desk of the facility, where there were sign-in procedures with nametags for visitors and fluorescent vests. The nametags also had emergency evacuation procedures on the back. The team was lead by the Health and Safety Delegate, who is in charge of ensuring that all of the occupational health and safety procedures are followed. His particular background was not in dealing with fires, but he had had experience with evacuations. He has been working on the job for 9 years.

The visit concerned only the building with the fire engineering, a large, open distribution building with an extended canopy that caused the need for a fire engineering report. The team was lead around the building while having the opportunity to ask questions of the Health and Safety Delegate leading us. While walking around the facility itself, there were no major deficiencies in the visible fire safety systems, with all of the fire extinguishers and hose reels present and maintained. Evacuation paths were clear, and there was an active effort to keep them clear during work hours with frequent housekeeping. The team was told that there is no cargo present at night. However the team cannot verify this claim due to the time of day of the site visit. Many of the doors along the outside of the building were open, as expected, but our guide said the policy is to keep them closed when not in use.

The alarm system was the primary concern for this site visit, as it was one of the PBD alternative solutions from the fire engineering report. There is no automatic alarm system using smoke or thermal detectors in this building, and there are no break-glass manual fire alarms. Fire detection relies on humans, either people working in the building during the day or security guards watching the building via CCTV (this is not a fire safety system, but is a means of detection since the security gatehouse is suppose to have the cameras being fed to them), being able to call security, where security will send the signal for a full evacuation and call the brigade. There are trained fire wardens throughout the facility who can help facilitate both fire suppression and egress.

The CCTV is helpful to detect a fire, but the CCTV was not a fire safety system. Having the Security Gatehouse manned at all times is a part of the fire safety

system because it is a vital link in the communication chain so that the gatehouse can notify the fire brigade there is a fire, which it was manned at all times. At the time of the site visit, there was no one watching the CCTV system, with only one screen showing one view from an external camera. The security staff was not able to view feeds from any of the other cameras, at the time of the visit, which were in the building, as the management change was to allow management to have primary access to these cameras. In this case, the CCTV could not detect a fire because those cameras were not feeding to the monitor. The building relied on someone spotting it. This did require everyone to know the emergency procedures which the team was notified that the staff was trained in this manner. But the other flaw with this system is that it is possible to not get full notification, as people near a fire may evacuate, and even call 000 for the brigade, but security won't get notified unless someone calls security.

A somewhat less complicated flaw concerned the fire control panel, which lacked sufficient labels and maps to determine where a fire is.

The Health and Safety Delegate guiding the visit appeared to be quite aware of how systems should work, and the evacuation procedures had been tested on a few occasions. The safety systems are checked every 6-12 months by outside contractors which then will report to the health and safety delegate to fix any problems. During a chemical spill emergency, there was a full evacuation of the facility, which showed that it was possible to evacuate without significant problems due to system problems. The largest problems noted were that some people could not be convinced to evacuate, in particular the truck drivers whose trucks may have been in the building, or external contractors who wanted to finish a task before leaving. In a separate incident, there was a fire, which was contained to a metal bin. In this case, there were only 6 people in the building, so evacuation was painless, but there was an attempt to fight the fire, which resulted in some burns as someone tried to climb the metal container the fire was in.

The Health and Safety Delegate told the team that fire wardens had training, usually supplied by the MFB, in how to use various types of fire extinguishers, and all employees had a general induction where this information was discussed. He was

aware of how the alarm system was supposed to function, but did not know about the issue with no one watching the CCTV system.

Issues Noted:

- Fire detection system
 - Automatic sensor system (smoke, thermal) deleted as a part of the PBD
 - Intended system relies on human spotters to call security, and security will call the brigade.
 - There are also CCTV systems so that security guards can watch for fires and report them from the security building. Due to a recent change, there was only one camera feeding the monitor in the security gate house. There was only one view available, and it was to an external camera. Though this was a means of detecting a fire, this was not a system dedicated to fire safety.
 - **Flaw:** Insufficient coordination for alarms, as it would be possible for an employee spotting a fire to call 000 to get the brigade, but the rest of the facility may not know about it.
 - **Flaw:** Some of the exit signs were not lit.

- Fire Control Panel
 - **Flaw:** No labels on panel to indicate where the zones are, and no map easily visible near the panel.

C.6 Building F

Age: 2 Years

Description: Multiple occupancy warehouse and office, with a large open warehouse area and an adjoining office section. There is a ground-level carpark outside of the

building, and the canopy that extends from the building does not constitute a 10a carpark. The warehouse section has a high ceiling, and is effectively two stories.

Building Section	BCA Class
Main Warehouse (With upper and lower Mezzanine and non-mezzanine floors)	7b Warehouse
Front office area	5 Office
Lower ground-floor carpark	7a Carpark

Stories: Effectively 2 stories for warehouse, 1 story for office section. Predominantly single story in the warehouse except for over the printing rooms.

Usage: Occupied a company that will print and store textbooks on this site. Printing processes occur in separated rooms, while storage is in racks in the open warehouse section. The racks within the warehouse will include boxed board games, plush toys in boxes, books, bulk paper and plastic toys in cardboard boxes.

Construction: Type A

Fire Safety Systems:

- Self-closing fire doors on side facing adjoining property
- Hose reels near exits

Occupant Constraints: All occupants are assumed to be awake, alert, mobile and familiar with the building. The occupants should be able to escape the room of origin of an open fire with no difficulty. There is no dependence on trained staff for evacuation, and the number of occupants will be less than 100.

Areas of deviation from DtS Requirements:

The deviations listed in the Fire Engineering Report are:

1. Permit extended travel distances to a single exit from upper warehouse floor of more than 20m.

2. Permit openings less than 1.5m from fire source features, such as the proposed northwest corner warehouse self-closing exit fire door
3. To permit reduced FRL to external walls and roof parts required to be of Type A construction.
4. To permit reduced FRL to internal elements of a building required to be of Type A construction.

Issues listed outside the Fire Engineering Report:

5. Permit fire hose reels short falls in the warehouse area, as required by the BCA
6. Deletion of automatic sprinkler system, a concern highlighted by MFB

Resolving Deviations from Deemed-to-Satisfy

Extended Travel Distance: (BCA Clause D1.4c requires that no point be more than 20m from exit or from decision point between exits with total distance of 40m) Extended distance is 30m and the difference is rationalized by the average ceiling height from ground floor of 9m, and average ceiling height from upper floor of 5m, so the occupants will have more time to escape. Meets performance requirements DP4 and EP2.2 conditionally assuming good management policies and practices.

Openings less than 1.5m from fire source features: Exit doorway is within 1.5m of adjoining property line. This problem is solved using a -/60/30 self-closing fire door. Assumed to be closed unless used for the passage of people, and will not be exposed to severe fire conditions.

Reduced FRLs in external walls and roof: The walls have a FRL of 180/180/180 instead of 240/240/240, and the roof uses combustible skylights. The report provides quantitative analysis and comparison to international codes (none cited) to support a reduced FRL in the walls when analyzed for the purpose of preventing fire-spread to adjoining properties. The roof variation is rationalized with qualitative interpretation of BCA requirements in comparison with other building codes, so that the skylights will not result in fire spread to adjoining properties.

Reduced FRLs in internal components: Through entirely qualitative analysis, the engineer assumes that because structural supports are spread out over a large area unlikely to simultaneously be involved in a fire, the reduced FRLs are reasonable with respect to preventing structural failure and fire spread.

Deletion of Sprinkler System: Due to size of the area, there are usage requirements to ensure that the rack storage section of the warehouse is not an excessive hazard (volume > 2000m³ and height > 4m). Based on the plans and the limited size of the planned racks, the warehouse storage does not technically constitute an excessive hazard. Based on floorplans, the maximum volume will be 1700m³.

Fire hose reel shortfalls: Due to the large size of the floor, in order to get full hose reel coverage, hose reels would need to be placed away from exits, making retreat after attempting to fight a fire more difficult. This allows for better life safety considerations.

Policies

- Management regulates fire prevention and response
 - Good housekeeping
 - Ignition control
 - Regular staff training in emergency response and evacuation procedures
- Fire Safety Management
 - Establish procedures
 - Allocate responsibilities
 - Regular training
 - Maintain and adjust procedures as necessary
- Fire Emergency: procedures should include all necessary areas to facilitate firefighting, evacuation, and calling of the brigade.
- All fire safety training and drills should be documented in a logbook
- Housekeeping
 - Combustible materials separate from ignition sources
 - Store flammable liquids in appropriate containers

- “Recognition of potential hazards” (no details)
- Ensuring escape routes are clear
- Ensuring fire doors are closed
- “Waste control” (no details)
- All checks logged.
- Maintenance
 - All fire safety systems should be maintained on a regular basis in accordance with Australian standards
 - Competent persons should examine potential sources of ignition such as gas, oil and electrical installations
 - All tests and checks recorded in logbook.
- MFB Required: Must check that racks are not an excessive fire hazard on a monthly basis, and this check is on the Essential service list.
- Annual inspection to ensure that class and use of building remains the same

Occupancy Permit Requirements

- Essential services maintained as per schedule
- Annual Essential services reports issued
- Due to lack of sprinkler system, the occupancy must not be an excessive hazard (Storage volume > 2000m³ and height > 4m)
- Warehouse roof lights may extend to within 3m of property boundary subject to roof lights being of polycarbonate or unplasticized PVC, or equivalent as per FER.
- Development, implantation and maintenance of fire safety measures listed in FER (Reproduced in Policies section)

Modeling assumptions

- Combustibles randomly distributed in warehouse area
- Fire doors near adjoining property closed unless people are moving through them
- Means of egress are free and unobstructed, with no locked doors.
- Exit doors intact, functioning hardware, swing in direction of egress where required.

Areas to check during site visit:

- Evacuation routes need to be kept clear of combustibles
- Fire doors must not be propped open
- Door closer systems (including automatic door closers near the side facing the adjoining property) need to be functional
- Hose reels should be in place, usually near exits.
- Maintenance logs for all checks should be available
 - Checks for volume of stored material
 - Housekeeping checks
 - Essential safety systems
- Rack storage cannot be increased beyond racks on plans – storage cannot be excessive hazard: Storage volume > 2000m³ and height > 4m
- No obstructed egress doors (locks, fasteners, etc)
- Combustible materials stored away from ignition sources
- Flammable goods in marked containers
- No excess waste in building
- Must make sure that the area between the adjoining buildings is clear and there is no debris that would allow fire spread, or extensions to the roof.
- Management policies
 - Regular drills and training (logged)

Interview with Managers

The particular areas targeted by this interview largely concern the storage area and its limitations – sprinklers will be required if the racks increase in size from the original plans. Of general interest is the reliance on outside contractors to perform maintenance.

1. Background

- a. What sort of Educational Background do you have?
- b. Can you describe your job and some of the responsibilities it entails?
- c. What sort of experience and training have you had related to the use of this building?

- d. How long have you owned/managed this building/facility?
2. Building-Specific Information:
 - a. How is housekeeping performed? What is recorded? Who performs the housekeeping?
 - b. How much is stored in the warehouse area of the building? Do you experience any changes in the amount of material stored?
 - c. How are employees trained in emergency procedures?

Site Visit Notes

Site Visit Notes:

The team visited the building with two MFB inspectors, and were accompanied by a manager in charge of maintenance for the building, among other tasks. While the building included an office area and a carpark, the focus of the fire engineering report and the team's visit was on the factory/warehouse area.

Throughout the visit, hose reels and extinguishers were in place, maintained properly, and were labeled, with few small exceptions.

The first area examined by the team was the printing room on the first floor (enclosed within the main warehouse). This area had very heavy fuel loads due to the pallets of paper throughout the room. This would present an egress path hazard due both to the increased difficulty of moving through the room with stacks of paper, but and additional hazard due to the fact that the obstructions are combustible.

In the main warehouse area, the primary area of concern for the fire engineering⁶ was the volume and height of the material stored. In order to avoid a sprinkler requirement, the volume must remain under 2000 m³ and the height must be less than 4m. The floor plans showed 4 long shelves which were used to calculate fuel loads at a volume of 1700 m³. The actual storage was much more extensive than

⁶ The fire engineering report actually had very little mention of the lack of sprinklers, however there was an MFB requirement placed on the essential services list (and occupancy permit) to ensure that the contents did not become an excessive hazard under the BCA.

indicated, with 5 long racks and pallets of goods stored to heights of 5.6m to 6m. There were also significant volumes of combustible material on the floor of the warehouse area, which add to the total fuel load of the area. Also of note was one exit, which had empty pallets placed in front of the door, and egress would require stepping over or removing the pallets. This particular issue is probably the easiest to fix, as it would only involve putting the pallets someplace else.

Another of the issues the PBD dealt with was the close clearance to the boundary lines and the team checked the exit doors and egress routes outside the building. The side of the building closed to a boundary line provided a narrow, but legal egress path to the front of the complex. This should be within the requirements of the fire engineering.

Issues:

- Storage of combustible goods
 - DtS required no more than 2000 m³ or 4 m high storage of goods in warehouse area.
 - Floor plans showed 4 long racks, with an estimated volume of 1700 m³
 - **Flaw:** 5 long racks were present, as well as significant amounts of material on the floor on pallets.
 - **Flaw:** While the racks were just under 4 m high, there was storage of pallets of combustible goods on top of the racks, pushing the height to 5.6 and 6 meters on the shelves mentioned.
- Egress Pathways
 - Printing room had large volumes of boxes (filled with paper)
 - **Flaw:** Egress path not entirely blocked, but makes egress difficult.
 - **Flaw:** Egress path is obstructed by combustible materials
 - **Flaw:** Exit door from main warehouse area blocked by pallets – this can be fixed easily.

C.7 Building G⁷

Age: Still under construction at the time of the project.

Description: The complex has multiple parts, all over a Class 7a carpark in a shared basement.

Section Name	Levels	Classification	Comments
Aged Care Complex	2	9c (Aged Care)	4 wings of bed-sits on each of two levels, 100 units, large open common areas
Mansion	2	2 (Apartment), 9b (Public)	Refitted to apartments
Apartment Towers	2	2 (Apartments)	

The primary area of concern in the Fire Engineering Brief (FEB) is the Aged Care building, which needs more extensive fire safety precautions due to the aged residents. This building is the largest of the buildings in the complex, and incorporates more fire safety systems than the other buildings.

Stories: 2 above ground, 1 level shared carpark in basement

Usage: Aged Care Facility, occupants consisting of aged residents that may require significant help with evacuation, staff consisting of trained and alert people able to facilitate evacuation.

Construction: Type C

Fire Safety Systems:

⁷ No site visit was performed for this building as it was discovered to still be under construction at the time.

Automated Sprinkler System in aged care facility and mansion – includes concealed spaces and roof spaces.

Smoke detection system – fully addressable system, battery backup to main panel. Magnetic hold-open devices, with manual release switches, for smoke doors that are held open. Activation of smoke detectors in common areas shuts down mechanical air handling systems.

Occupant Warning System: Staff has pagers to find out about emergencies, used for coordinating response. Public address system to inform occupants.

Hydrants, Hose reels, fire extinguishers, fire blankets, emergency lighting and signage all available.

Emergency lighting system.

Occupant Constraints:

Residents – Assumed to all need help evacuating with a one-to-one staff to resident ratio, but the necessary level of help varies. Those in common areas were modeled as not needing help to evacuate, as these residents would be awake and alert. They need help both in evacuating and for notification of emergency. Those that need the most help are those that are in the wings section of the aged care complex (bed-sit area). The residents in the common areas are assumed to be more aware and active, and will need less help to evacuate. In this instance, it was also assumed that more able residents will be capable of helping the less able residents. All residents are assumed to comply with evacuation instructions and act in best self interest.

Staff – Assumed awake and alert with sufficient numbers and training to facilitate minor fire fighting tasks (not modeled), notification and evacuation. Staff will have pagers to communicate during an emergency. Design calls for at least 4 staff available at all times, but numbers may fluctuate depending on number of aged residents and level of disability. This number may drop during some hours of the day.

Areas of deviation from DtS Requirements: (Numbers match list on page 16 of FEB, section 4, revision 01)

The report lists 13 areas where the design deviates from DtS requirements, with 8 concerning the general construction of the buildings relating to fire resistance, and the remaining 5 concerning access and egress. There was an additional deviation in the first version of the FEB that deleted the fire rated protection for the steel support members in the carpark, and a fire scenario still tests this condition, but it is not listed in the most recent list of deviations.

1. Allow first floor in 9c, used for separating smoke compartments, to be solid timber joists with 13mm plasterboard, in lieu of 60 min FRL
2. Allow first floor and walls in existing mansion to remain with half required FRL (1.5 hrs rather than 3 hrs)
3. To allow smoke zones larger than 500 m²
4. To allow load bearing walls supporting first floor in 9c part to be lined with 13 mm fire grade plasterboard rather than 60/60/60 FRL
5. Allow new/existing party walls at top floor between apartments in mansion to finish at underside of ceiling instead of roof covering
6. Delete fire rated top enclosure for stair shafts in 9c part
7. Allow openings and walls of 9c part to be within 6m of apartment building, which lacks the required FRL or protection to Spec C3.4.
8. Allow roof/ceiling space smoke walls to be lined with 13mm plasterboard on one side only
9. Delete separation between rising and descending stairs in 9c area and in apartment stairs
10. To allow the point of choice to two alternative exits to be more than 20m (28m in basement and 22m on the ground and first floors of the 9c part) and the distance to an exit in the basement to be 46m in lieu of 40m.
11. Required exit is smoke isolated stair (5) rather than fire isolated, stair discharges internally rather than to outside, as required of fire isolated stairs.
12. Travel from stair discharge in 9c part to pass within 6m of building without 60/60/60 FRL or self-closing openings
13. Allow smoke doors in 9c to swing against direction of egress

14. Allow unprotected steel beams in the carpark under the 9c area in lieu of 120 minute FRL protection⁸

Resolving Deviations from Deemed-to-Satisfy

Oversized Smoke Zones (> 500m²)

- First Level Resident Sleeping Area (540m²)
 - Due to staff facilitating an evacuation during a fire, this change does not affect life safety.
- Ground Level Common Area (560m²)
 - Residents are likely to be alert and will be able to evacuate, with staff help, fast enough to preserve life safety.

Reduced Fire Resistance Levels (1, 2, 4, 5, 8 from list)

- Sprinkler systems that include concealed and ceiling spaces will help to suppress fires, and not result in increased hazard.
- Staff will be able to evacuate before the sprinkler systems can be overwhelmed.
- All occupants (residents, staff and visitors) will have affiliation to the building.
- Staff will help to fight fires or notify the brigade in emergencies.
- Low fire loads are expected (400 MJ/ m²), and hazardous materials are mostly unlikely (except for Oxygen cylinders or medical supplies).
- Fully developed fires will not likely occur due to the sprinkler system.
- Fully addressable smoke detectors system will alert staff prior to sprinkler activation, and staff will coordinate evacuation using pagers and public address system.

Deletion of fire rated top enclosure of fire rated stair shafts in 9c part of building

- Removal of this enclosure may allow fire to spread to stairs prior to brigade intervention, but this is unlikely given the trained staff and sprinkler system.

⁸ Inconsistently listed - in first revision, but not second, even though fire scenario designed to test this particular scenario still exists. Not in either of the final lists of deviations, however.

- Other fire-rated stairs available in the building and each shaft is separated from each other, so spread is unlikely.
- Occupants will be able to evacuate prior to fire spreading into the stairway.
- Ignition is unlikely inside the stairwell itself.

Allow openings and walls of the buildings to be too close (<6m and < 18m) to the apartments without the required FRL or protection.

- Fire spread from stair 4 is unlikely, as the stair will be kept sterile.
- Sprinklers will prevent the spread of most fires
- Heat transfer will be insufficient (with sprinklers active) to cause ignition in adjacent buildings.
- See rationale for reduced fire resistance levels

Delete separate rising and descending stairs

- All occupants will be familiar with the exits
- Signage will be present to prevent mistaken egress to the basement rather than ground floor.
- Occupants are expected to be awake and alert while using stairs and immediately comply with any fire cues.

Allow extended travel distances to exit (basement) and to point of decision (ground and first floors of 9c area)

- Travel times do not increase significantly enough to cause life safety concerns.
- Occupants in the basement are likely to be of sound mind and body
- Residents will have staff available to help the evacuation
- Occupants population in the 9c part will be approximately 100 people, with awake and alert staff at all times.

Exit stair (stair 5) discharges internally and is only smoke isolated

- Located in small smoke compartment
- It is only necessary to travel down one floor to egress, with an exit 8m from the internal discharge point
- Alternate fire isolated stairs available
- No beds in lower section accessed by stair

Allow travel from fire stairs to pass close (<6m) to apartment building not meeting 60/60/60 FRL or having automatic self-closing openings

- Fires in the bedsit area are unlikely to be significant due to the sprinkler system
- Staff would coordinate the evacuation to avoid going near any fires, and this stair would not be used if the route were not clear of fire

Doors swing against direction of egress

- Opening the doors causes a several second delay, but these delays are mitigated by staff response, and single-occupancy of the rooms.
- Sprinklers will prevent significant life safety dangers
- Due to the small number of people in a wing (18), a 'crush' of people against a door is unlikely to occur, especially given the staff.

Evacuation Assumptions

- Fire sprinklers not obstructed
- Fire and smoke doors not held open in an emergency
- Staff members trained as to what to do in an emergency – includes closing doors after evacuation.
- Design dependent on working sprinklers.
- Compensate for oversized smoke compartments by assuming active residents (no one is sleeping) in the common areas and sleeping residents in bed-sit area can be helped by the staff.
- Tactical fire plans provided in all public areas, laminated and well labeled with relevant fire system details (egress path, hydrants, hose reels, exits, evacuation assembly points, etc)
- Management policies
 - All employees and contractors have fire safety information and fire safety procedures (specific to building) – staff has training and practice handling evacuation procedures.
 - Numbers of staff need to be maintained relative to the number and needs of the residents.
 - Remove combustibles from escape paths
 - Regular maintenance of equipment.

- If building changes, the Tactical fire plans need to be updated.
- Annual audits of procedures.

Evacuation Notes

- Sprinkler system assumed to contain fire to room of origin, and other precautions deal with a fire that continues to spread.
- Strategy is not to evacuate to the outside, but to get occupants to “safe areas” that could be in the building. Also described as getting to another smoke compartment.
- Occupants may need to move through visibility-limiting smoke to escape

Modeled assumptions:

- One fire at a time
- “Safe haven” defined as a “compartment containing a fire rated stair outside the smoke compartment of fire origin.”
- Occupants do not engage in fire fighting in models.
- All essential services functional

Areas to check during site visit:

- Sprinklers unobstructed
- Sprinkler maintenance – Should meet standards, look for logs of tests performed
- Smoke doors (automatic closing) work properly and are not impeded
- Doors have 3mm gaps at sides and 5mm at top and bottom
- No doors propped while unattended (models required doors closed)
- Clear escape paths
- Signage to indicate exits (particularly in stairs)
- Tactical evacuation plans available
- “Suitable” number of staff available – should look for logs or similar
- Residents in public areas require less help by staff (or are attended by staff), and the most able will be able to help the less able in an evacuation.
- All staff have pagers to coordinate emergencies
- Emergency plans available

- Wall penetrations smoke sealed – won't be able to judge materials, but can see if there are any gaps. Should also look for penetrations made after initial construction.
- Availability of fire extinguishers, hose reels, fire blankets
- Fire stairs are sterile, especially stair 5, near the middle in the 9c area, and stair 4, near the apartments.

Interview with Managers

Note: We will need to avoid asking direct questions of the staff to get them to volunteer information without leading them into an answer. The questions are intentionally vague under the expectation that the staff will happily give details if they think they are doing things correctly. Targeted information will be in parenthesis and will give the follow-up questions for each area.

1. Background
 - a. How many residents are there? (where staffing levels might be)
 - b. When did the new facility open? (this might be very recent)
2. Staffing
 - a. Are there people here all the time? Even at night? (minimum staffing information)
 - b. What sort of experience and training does the staff have? What do you need to do/know to work here? (emergency training, fire appliance use, regularity of training)
 - c. Is there some sort of housekeeping in the hallways? (Clearing escape routes of fuel – should try to comment on current state, such as “It's very clean in here...”)
3. Emergency response
 - a. What happens in the case of a fire? (evacuation plans – specifically where they are taken, coordination – pagers and public address)
 - b. What do you expect in the case of a fire? (sprinklers, alarms, evacuating through smoke)

Appendix D: Interview Notes

Because anonymity was a condition of many of the interviews, the interview notes are only identified by subject numbers for the purposes of this paper.

D.1 Subject 1

Fire Safety Engineer in Victoria

- Manages group of FSEs working for fire engineering firm.
- Works with a variety of projects such as residential, commercial and industrial buildings as well as infrastructure.
- Generally get involved fairly early on in design process, at a point when the building design is complete enough to see if it will require an alternative solution.
- Clients are typically well educated.
- Knowledge of the benefits of PBD in Australia is pretty good.
- Most projects involved an FSE.
- Often not involved in actual construction because there is no requirement to have an FSE after the building permit is obtained.
- In NSW an FSE is required to sign off on the building after it is finished.
- In Queensland it is fire brigade policy for an FSE to sign off on a building after it is finished.
- Usage determined by the drawings themselves, i.e. drawing will say label an area as retail or residential.
- No accounting for change in use. It is stated on report that if the usage changes, the design needs to be reassessed.
- Ideally, when a building use is changed such that it needs a new permit the FSE will get involved early in the process.
- Often, the building surveyor will forget and not get the FSE involved until the end of the process.
- Occasionally, the building surveyor will forget entirely about the FSE.
- Common for buildings to change from retail to office.

- Also a gray line between Class 2 buildings (apartments) and Class 3 buildings (hotels).
- Warehouses often change what is stored, which affects the fuel load but does not change the use as far as the regulations are concerned.
- Good building owners/managers are aware of requirements of fire engineering report and what they can and can't do.
- Change in ownership can often result in a loss of information.
- Good tenants will have the building checked when they buy it. Only about 20-30% does this.
- Developers and contractors want to build as cheap as they can.
- Sometimes you can delete a fire safety system and the building will still be safe.
- It's up to the owner sometimes to decide how much risk they are willing to take.
- Most insurers have little impact on the design. Some get involved and impose their own requirements on the developer.
- No effort has been made to educate insurers.
- Common deviations from DtS are smoke control systems and extended travel distances.
- Easier to incorporate alternative solutions earlier in the process.
- Building permit is most common method of communicating. Often written in very general terms.
- ICC requires "bounding conditions" to be displayed. These are the important aspects of fire safety design. Easier to check and more detailed than permit.
- Permit level of detail often depends on who writes it.
- Bounding conditions pick up not only the systems, but other parts as well (fuel load, compartmentalization, etc.)
- Singapore uses operating manual. Produced by FSE and written specifically for non-technical people to inform them of most important areas of report.
- Building managers would probably use this info if provided in a way they understood.
- Often will ask in his reports that something, like extra maintenance, be added to the essential safety measures.

- Quality of building surveyors ranges. Some will sign off on things even if they don't really understand them and haven't thoroughly checked them.
- This is often because the building surveyor is employed by the developer and wants to keep the customer happy.
- No real policing of building surveyors in Victoria.
- Inspections by fire brigades and municipal building surveyor are primary enforcement methods. Not enough manpower.

D.2 Subject 2

Fire Safety Engineer with New South Wales Fire Brigade

- Fire brigade makes comments on designs incorporating certain fire safety features.
- Comments are optional, but if they are incorporated then the brigade makes sure the requirements are met.
- Problems with buildings are fairly common; chances are you will find them in any building you look at.
 - Sprinklers turned off in one building.
 - FRLs not implemented in an apartment building (people could smell neighbor cooking)
- Example: warehouse with goods piled too high, exit signs are obstructed.
- Yearly inspections are supposed to be performed on the essential safety measures. This isn't always done.
- If it isn't done, the brigade can order non-structural work be done to fix it.
- Can tell people to stop using a building for certain things, can't completely shut it down. This is done very rarely.
- Fire brigade has to pay for any add-ons it orders to be put on a building.
- No requirement that FSE has to provide information to building owner/manager in an understandable manner. Some do, some don't.
- Most of the time, brigade comments are taken into account because of an example made of a few people who didn't.
- Brigade doesn't have enough manpower.

- Common alternative solutions: reduced egress width and extended length, smoke control, reduced FRLs.
- Building surveying and fire engineering have two different focuses: building surveying focuses on the regulations and fire engineering focuses on finding the best way to do things.

D.3 Subject 3

Fire Safety Engineer in Tasmania

- Designs fire safety systems based on the fire engineering reports.
- Hasn't seen much in the way of major usage change in Tasmania (referring to classification change).
- Most common change in reduction in number of fire stairs.
- Example: Narrow, 20 story building that the designers wanted to only have one stair. This is a problem when trying to get fire fighters up the stairs and evacuees down. Ended up not being built because the fire brigade wouldn't approve.
- Often the one he deals with is the developer, not necessarily the end user.
- Owners/managers don't always pass on information regarding what needs to be done to maintain the safety in the building. This is often due to fire safety being a low priority for them.
- PBD is often used to achieve the most efficient and practical design.
- Cost not as important.
- In Tasmania, the FSE becomes involved either by the architect realizing that he's going to need fire engineering as he progresses, or the developer deciding the building will be fire engineered no matter what.
- FSE needs to be involved as early as possible. Had a building that was built without proper approvals beforehand and needed an FSE to come in afterwards and sort everything out.
- The occupancy permit should require the signature of an FSE.

- Queensland has a good idea where there is a sign near the FIP which says that the building is a fire engineered building. Trying to get that implemented in Tasmania.
- Building owners who are involved in design are more aware of the needs of the fire safety solution and more willing to meet those needs than an owner who buys the building later on.
- Building owners are required by law to make themselves aware of these needs.
- PBD is too new in Tasmania to get a good sense of how well it is working right now.
- Local insurance companies are going to be more aware of the requirements and what's going on in a building than companies in other states or countries.
- Fire services in Tasmania can inspect but ultimate decision making power belongs to the local council. The fire services have some power to prosecute but don't like to use it.
- Fire service doesn't have enough manpower.

D.4 Subject 4

Municipal Building Surveyor and Deputy Building Surveyor⁹

- Occupancy Permit should contain all the information regarding how the building is to be used and how the fire safety systems need to be maintained.
- The communication of these requirements depends on the building company and is generally not very good.
- Issue arises when the developer hands the building over to the owner. The owner might not understand everything that is given to him.
- Information can be lost when the building is transferred from owner to owner too.
- It is required for the essential safety systems to be maintained and the owner has to sign off on this every year.

⁹ This interview was done as a combined interview with both present.

- Sometimes difficult to find the necessary information for a building when performing an audit.
- Building surveyors who sign off on PBDs have a pretty good understanding of it from the course they are required to have taken, if not they have to give it to either an FSE or a qualified building surveyor.
- Owners/managers don't always know enough to do their job properly. Trying to set up information session to educate them.
- Large buildings often owned by corporations and can be very complex to manage. Even more difficult when there are multiple owners (in a subdivided building for example, where each apartment, condo, etc, is owned by different people) and it is unclear who is responsible for common areas, corridors, etc.
- Some managers are just ignorant of their responsibilities, others are aware but too busy to do anything, and others know and are trying to sneak under the radar.
- The Municipal Building Surveyor has the ability to prosecute offenders but prefers negotiation.
- The city focuses on high risk buildings, such as nightclubs, hotels, etc, where there are a large number of people with a high potential for casualties.
- Regulations currently don't account for small issues that don't change building classification.
- Example: Apartment building with two penthouses on the top floor and only one exit stair. Penthouse doors had button that could be pressed to automatically open the door in case of an emergency. New tenants moved in and were worried about security so they padlocked it.
- Nothing in legislation governing passage of information from seller to buyer regarding safety issues.
- Not enough building inspectors to inspect every building every year.
- Trying to get the message across that if the building isn't maintained properly, the insurance policy may be void. Hoping the insurance companies will support this.
- Lot of developers use fire engineering as a way to lower costs.
- Issues with apartment buildings being used as short term accommodations.

D.5 Subject 5

Building Surveyor in New South Wales

- Focus is on how the process is supposed to work, very little on the practical details.
- Position is to review reports, with understanding of the FSE end of the work, and determine if the reports are sufficient.
 - Liability for signing off on bad designs
- Inspections occur after building construction
- PBD areas
 - Deleting sprinklers – replace with smoke exhaust systems
- Influences on design
 - Insurance – insurers are becoming aware of how PBD works, and are paying attention to some of the details.
 - Money – many clients want to find cheaper solutions, and will pay FSEs to find the easy solution, rather than the safe one.
- PBD Flaws
 - Paperwork not sent to council – process isn't followed, not effective policing.
 - Responsibility is on the owner – but many aren't sending in the documentation and there are unsafe buildings.
 - Badly written reports are a problem, 10 out of 150
- Communication
 - If there are bad reports, the surveyor will tell the client that they have chosen a bad FSE based on low cost.
 - If the changes go by him, then he reviews the report and documentation before informing the client to go back to the FSE.
 - Clients don't really understand it, unless they have engineering experience.
 - Architects sometimes understand the problem, sometimes not
 - Builders just beginning to understand it
 - If clients understood the report better, it would improve things

- Don't understand the steps behind the report, or fire engineering. Only told they will save a certain amount of money, but details left out.
- It would be helpful if there were sections written into reports designed for non-technical managers.
- Very confusing for new building managers, people more recently in the field have better ideas of how things work.
- After construction
 - Legislation says every 12 months everything tested
 - Outside contractors provide the testing
 - Onus on the owner to evaluate building
 - Inspections consist of checking things off on a list, specifically focusing on fire safety systems (other elements not listed, such as fuel load/distribution, etc)
 - If the building does not pass inspection, the contractors won't sign off on it.
 - Council can issue a warning, but this is not usually done, as there is no manpower after to police any of this.
 - Cannot get people, improvement unlikely.
 - FSE modifies report for changes
 - Needed if there is a major change such as adding offices to a warehouse
 - Report goes back to FSE for changes, reviewing process occurs, passed on to builder as part of the construction permit.
 - Certifier only has to go back to the FSE if there is a change to the fire engineering requirements
 - Only occurred about 3 times in his personal experience–
Example: shopping center with extended travel distances

D.6 Subject 6

Fire Safety Engineer with CFA

- Law in Victoria requires that owners maintain the systems in their buildings but many don't do this because it's not at the top of the priority list for them.

- Fire Engineering is a rapidly growing field; many more people want to use it for all types of buildings.
- Example: 25 million dollar (AUD) warehouse fire. Original use of warehouse was to store non-combustible metal car parts. Designed without sprinklers and without an automatic fire detection and alert system. Building changed hands and was bought by a transport company. Then used to store 150,000 liters of motor oil as well as a range of other combustibles, which varied from day to day. Building caught fire and by the time the fire brigade showed up, it was fully engulfed. The motor oil was contained at all and caught fire and started flowing out of building. It ignited the trucks outside and then flowed into drains before the fire brigade contained it. Building was still a warehouse even though its contents had changed so its classification was the same and no new permit was required.
- Legal mechanism for changing requirements on the occupancy permits when the use is changed but no real world understanding of it. Owners are generally too busy with other issues.
- A few insurance companies understand PBD and get involved and make their own requirements that must be met in order for the building to be insured.
- Often difficult for developers to get past the initial cost of fire safety and see the long term savings and other benefits.
- Example: Equestrian center, with large open middle and stadium seating around the edges. Plan was to put sprinklers only around the edges. The building was inspected and there were stables and feed in the middle. CFA recommended that they put hydrants in instead of sprinklers.
- First owner who was involved with design understands why things need to be maintained. Later owners might not and won't be as willing to do it.
- Requirements listed in fire engineering report need to be communicated to managers and understood.
- Engineers often rely on occupant intervention when doing their analysis.
- Building occupants don't always understand why they can't do certain things (like opening fire doors).
- PBD works great as long as everybody does what they're supposed to do. Human nature however often leads to shortcuts being taken.

- Public perception is important. Eventually, there will be a big fire with a PBD building and people might take the quick easy response and just get rid of PBD and revert back to prescriptive codes.
- Reverse engineering: developers/builders do something, like put in a wall without the proper FRLs *then* go back to an FSE and get it justified.
- Lot of pressure on developers to do things fast and cheap, fire engineering often seen as a get out of jail free card.
- Common uses of PBD: reduced FRLs, extended travel distances.
- CFA sometimes prefers the use of the Appeals Board, since they are legislated as being untouchable and are thus an independent body.
- Not always an independent check when using PBD.
- Buildings in the public eye (like MCG, Telstra Dome) are often better managed because of the attention and risk involved. Nobody really cares about the factory that nobody sees.
- Generally PBD is used to reduce cost. Occasionally used because the DtS isn't appropriate and doesn't provide the right level of safety.
- CFA has added difficulty of use of PBD for bushfires.
- More education is required for everybody involved in the building process.

D.7 Subject 7

Building Manager for Building A

- Been in industry for 25 years.
- Body Corporate responsible for maintenance of all common areas.
- Contractors are used to perform all of this maintenance. The Body Corporate doesn't employ any staff.
- Initially, the contractors are the ones who installed the equipment.
- Technical details left to contractor, there is no oversight. Assumed that a reputable company will do good work.
- Contractors often chosen by developer. Price is the biggest factor although the choices are generally limited.

- Maintenance info provided by developer and builder. Manuals produced to facilitate maintenance.
- Occupancy Permit is overall guideline but not referenced in day to day use.
- Maintenance companies are responsible for satisfying requirements on Occupancy Permit.
- Believes that most buildings are managed in similar fashion. Lots of competition, so a manager who isn't performing is at risk to be replaced.
- Wants to make sure regulations are complied with partially because of random checks performed by fire brigade.
- Not many professional managers have much technical knowledge. Dependent on the contractors for this.
- Doesn't use the fire engineering report, anything important in that would be on the Occupancy Permit.
- Feels that if he doesn't keep the building compliant, he could lose his job. It's also to protect his reputation.
- Committee must be appointed by Body Corporate. Some are more proactive than others. The committee at Building A is very proactive.

D.8 Subject 8

Fire Safety Engineer in Victoria (Performed the Fire Analysis for Building C)

- Usage of building determined through discussion with the other stakeholders.
- Not much change in use, as far classification, that occurs with apartment buildings. Only issue is changes from apartment to hotel which isn't that significant since the buildings are pretty similar.
- Issues can arise when owners or managers change and they aren't aware of the requirements.
- Example: A building's exit stair discharges into the lobby which must be free of combustible. A new owner comes in and wants to put in a couch or something which changes the fuel load.
- There isn't enough control over the actions of managers and owners regarding fire engineering requirements.

- Only check is that the manager must sign off annually that things are being maintained. But the problem is that the manager does not have the technical knowledge to do it.
- BCA classifies warehouses as high hazard, medium hazard, or low hazard based on what is stored.
- Little control, because it requires the end user to interpret the requirements of his occupancy permit.
- Depending on the building, insurance may come out and do an audit. Other times they just might ask questions about the use of the building.
- For large valuable buildings with valuable things inside, they will negotiate with insurer and involve them from the beginning of the process.
- Some insurance companies understand a lot about the process and the regulations.
- At the other end of the spectrum, an insurance company wouldn't accept a system that didn't meet Australian standards even if it would have been better.
- Majority of people in the property industry don't know much about process.
- Owners of large buildings and multiple buildings are becoming more aware of complexity of process and the benefits and limitations of PBD.
- FSEs try to take human error out of design by not basing it on requirements like keeping exit corridors clear.
- Regarding Building C, the building surveyor approached him about staged occupancy. He said it was complicated and requires that all parties be involved and agree on a strategy.
- Building surveyor has the responsibility to ensure that he only issues occupancy permits for buildings that are safe.
- The builder is responsible for making sure the building complies.
- Builder often won't get paid until the occupancy permit is issued, which is one of the motivators for staged occupancy.
- No regulations governing staged occupancy. Up to the building surveyor to impose requirements on the process.
- Legally, the building surveyor is qualified to make these decisions if he's taken the building surveyors course.

- Most can understand the fire engineering report but often not the complexities of fire engineering.
- Privatized building surveyors are just as good as or better than government employed building surveyors because it's their reputation on the line. For council employees they get paid no matter what so it doesn't matter.
- Builders are concerned with time and money, not with fire safety.

D.9 Subject 9

Building Manager for Building B

- Managed the building since it was completed
- Responsible for all the maintenance of the building
- Manages 5 buildings total, Building B is the smallest
- Been a building manager for about 20 years
- Building is largely used for short term accommodation
- Maintenance done by outside contractors
- Relies on feedback from occupants and regulatory officials to determine if things are being maintained properly.
- No technical background, not familiar with the alternative design associated with the building
- Relies on the occupancy permit to determine how the fire safety systems need to be maintained.
- Relies on the contractors to make sure they comply
- Uses primarily two companies for fire safety system maintenance (including fire extinguishers, exit signs, and ensuring egress paths are clear)
- These companies handle both inspections and repairs
- Building built to price rather than for quality
- People are provided with pamphlet detailing evacuation procedures and these are also on the door (only for apartments used for short term accommodation)
- Occasionally have problems with people leaving trash out in the hallway; this is quickly noticed and rectified

D.10 Subject 10

Building Manager for Building E (This person was interviewed on site during the site visit and also talked to over the phone)

- He was the health and safety delegate for the distribution centre
- The parcels were cleared out everyday before the end of the day
- In some rare cases the distribution centre would have some packages that were left there overnight, but it was never an excessive amount
- In the even rarer case that there was a strike, which has happened in the past, the packages either would never make it into the distribution centre and would be left in the trucks in the truck and trailer parking or the packages would be left in the distribution centre. He said the last time there was a strike, there was not a large amount of packages that were left in the distribution centre
- The delegate knew that excessive storage of parcels in the distribution centre was a potential safety hazard
- He knew that the sprinklers were deleted along with the smoke detection system
- He also knew the reason why the smoke detection system was deleted
- The delegate also knew that the building just went over the area that sprinklers were required
- He was under the impression that the CCTV was part of the fire safety system where the security gatehouse had the feed to all the cameras that were in the buildings. The security gate house at the time of the visit was only getting one camera view and it was of the gate that was on the other side of the street.
- During the follow up interview, he informed the group that the CCTV system was fixed and fed all the cameras to the security gatehouse which, since the follow up phone call was only 5 days after the site visit, showed the timely manner in which he resolved problems

D.11 Subject 11

Private building surveyors¹⁰

- No regulation governing small changes in building such as those that arise from change in tenants
- These changes aren't policed at all. No way to know how often it happens
- If there is a change of function within a use, the planning regulations might pick it up
- Occupancy permit may have limits on fire load, occupancy, etc. Recorded by council but not necessarily policed.
- Local council is really the only regulatory body
- Not all owners/managers actually take the time to read and understand the occupancy permit
- Don't always deal with the owner directly, sometimes deal with project manager or other representative of owner
- Ideally, they will deal with all stakeholders at design time
- Buildings often built with no owner in mind, building is built and then a buyer is found
- FSEs often come up with same solution so that the ultimate effect is that the DtS provisions have been expanded to these new fire engineered values
- PBD fairly young in Australia. Designers often start trying to meet the DtS and only use PBD if the DtS becomes impractical
- Very rare for buildings to be designed entirely using PBD
- Broad spectrum of building managers. Most are not aware of the intricacies of the needs of the building
- Fire safety not a primary concern for building developer/owner. More concerned with finding tenants
- Building managers are rarely involved in the design, and is often ignorant of the requirements of the fire safety systems
- Generally with factories, warehouses, offices, etc the final owner is not known at the time of design.

¹⁰ This interview was done as a combined interview with two building surveyors present.

- Usually, contractors give one year warranty with systems they install
- Insurers have some impact on how much attention is paid to fire safety
- Some organizations (government, hospitals, and some companies) have their own additional requirements. For example, mandatory smoke detectors in schools
- Most insurance companies have a good understanding of PBD
- Their office doesn't even consider single stair buildings. Some FSEs won't consider them either

D.12 Subject 12

A Private Building Surveyor, President/Owner of Surveying Firm

- Has seen many of the problems we have seen
- His business deals with audits and inspections of buildings and he sees all these normal "stuff-ups" all the time
- Private surveying does almost 80% of the inspections
- Checks the buildings in the area of the essential safety measures and all other aspects of the building that can impose safety risk and these checks happen once, twice, or four times a year for over 12,000 inspections
- The company also put all these checks down into log books and has the log book for every building they have ever performed an audit or inspection for
- Most people are driven by money
- Most people are "slack"
- Sometimes you will come across people that are very ethical and they tend to implement everything properly
- People that are paying money want the cheapest, and everyone receiving the money need a profit, which causes a degrading service
- These problems are happening all over Australia and has proof because he has companies in other states
- There isn't any legislation to enforce these regulations
- The reality is education doesn't work because the dollar is a stronger power

- Maintenance is a bottomless pit of money which is why a lot of owners and managers tend not to spend a lot of money on it because they would rather pay the fines due to the lesser amount of money that the fines are compared to cost of implementation or maintenance of systems
- Example: There was a building, a client of his, had a building high rise with all the safety systems, such as sprinklers, smoke detection, stair pressurization, and automatic fire brigade calling, etc., and he tested it one day on a Sunday in the morning when no one was in the building, and 60-70% of the fire safety systems didn't work. He set off some smoke bombs in the foyer and the lifts were supposed to go to the nearest floors to the ground without smoke but instead it went to the ground floor where all the smoke was. The stair pressurization system didn't work either. The fans that were supposed to start when the alarm was triggered didn't turn on. The fire brigade was supposed to be called when the alarm was triggered and the fire brigade was never called. The egress system didn't work. This was an owner that was doing something, but didn't work.
- There is a problem with owners that know there is a problem and are doing something about it and nothing works and owners that are not doing anything about it
- They inspect buildings and give the owners and managers a log book that has all the information they need to fix the systems and then they come back 6 months later for another inspection and they didn't fix anything. He would talk to them and ask the client why and they would respond because there are too many buildings I own and if I were to fix them all then it would cost me much more than a couple thousand dollars in fines.
- The legislation has to change so that the fines are just as more costly to the owner than the implementation and maintenance
- When the building surveyor issues an occupancy permit they give it to the owner and it is their job to inform who's in charge of what to do to maintain the building. This step is being left out in a lot of buildings
- Managers don't read the permit and don't understand why they have to maintain these aspects of the building where if they were to read it, they would understand this much better

- Example: In Sydney they have a client that had a high rise building and they picked on the doors and they wanted them to get rid of them because they were made out of asbestos. And they wrote in their log book that they had to make sure they abide by the public safety regulations. 6 months later they came back for another inspection and they took off all the doors on all 38 floors and now there weren't any fire doors into the stairs. They gave them a call of why this happened and the owner of the building said that they took off the doors but the new ones haven't come in yet. The doors had been off for almost 2 weeks before the inspection.
- Some of there clients left them and then came back years later because they provide great services even though they're more expensive. There are too many owners that go to other surveyors that cost half the price of them that don't even know occupancy permits exist
- Too many surveyors that don't necessarily take good care of there work
- Bottom line of cost and education
- The vast majority of senior building surveyors don't believe FSE that is because in Australia they can put a design forward with outcomes that they do not have to be accountable for.
- It is the building surveyor or the municipal building surveyor that is accountable because they are the ones signing off for it
- Developers shop around for surveyors to get someone in their "comfort-zone"
- If a developers come to there company without asking price and instead come in with a idea in their head like here is our building would you sign off on this and then delete something and then ask them if they would approve of that, they say get out of our office
- FSE design a safe building but that is right on the limit and all the safety systems have to click in all at the exact same time and this doesn't always happen all the time
- Not enough building surveyors!
- 400 building surveyors in Victoria, of which 1/3 of them actively don't issue permits. There are only about 333 operating building surveyors a 1/3 of those are very qualified and don't get the best buildings. You get the top end

building surveyors getting the best buildings, but now they are getting too many of them and then their work slacks.

- 31% of building surveyors didn't issue permits
- 69% of registered building surveyor were active in the last year
- 25% issued between 1 and 100 permits
- 14% issued between 101 and 200 permits
- 19% issued between 200 and 500 permits
- 11% issued over 500 permits
- Building surveyors don't charge enough
- The systems don't protect the surveyor enough
- A FSE should be accountable for his design and take liability for it
- Other building surveyors are going for quantity not quality
- A company that makes log books that are different from the ones people have been using and it is a scannable log book that way the building managers can scan it and send it back to the company and then give it to the appropriate people to keep record of it. This system catches if the companies are actually doing the repairs. Sometimes if the repair and maintenance companies know that a building is using the system, then they will bring more people and spend more time at that specific building. This will cause the other buildings that the maintenance company has to not get there maintenance and then they fall behind, so it is a lack of people that causes lack of maintenance.
- The technicians make more money out of installation and less on maintenance, so they tend not to take time to do the maintenance
- They should (the MFB or the Municipal building surveyor) pick out a high rise or an age care facility or a hospital and really dig into them. Make them pay for all there mistakes and make them fix all there building problems to make an example so that everyone else will want to fix there buildings before they get caught. Put some fear in them.