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The Development of a Link Between Prescriptive Regulations and the Performance Based Approach

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Abstract

Performance Based Design (PBD) has various advantages in the design of new and existing buildings. However, the lack of a well-defined framework causing excessive freedom in the design leads to a variety in achieved levels of safety. The need for a consistent level of safety is recognised if PBD is incorporated into a legal system. A robust framework can solve this inconsistency. Deterministic input parameters for a PBD framework are discussed. A possible solution is proposed to make the relationship between input parameters in a framework more explicit.

The focus of this thesis is the development of the New Zealand (NZ) PBD framework in the Belgian context. One of the adapted input parameters in the evolution of the NZ framework is shorter pre-movement times. A survey was conducted with a response of 194 participants. Results are not in favour for the application of short pre-movement times in Belgium. Belgium employs a prescriptive fire safety legislation. A deviation is possible but challenging and procedural complicated. A case study was performed on a compartment in a high-rise building using the NZ framework and a Belgian comparative approach. A higher level of safety was demanded in the NZ approach. However, an exact adoption of the PBD framework for Belgium would not be recommended.

Abstract

Performance Based Design (PBD) heeft vele voordelen in de ontwikkeling van nieuwe gebouwen. Te veel vrijheid in ontwerp leidt echter tot een verscheidenheid in behaald veiligheidniveau. Indien PBD deel zou uitmaken van de wetgeving dan moet een consistent veiligheidsniveau gegarandeerd kunnen worden gebruikmakende van een framework. Vele input parameters zijn gerelateerd aan elkaar in zo een framework. Een ratio wordt voorgesteld om deze relatie tussen parameters expliciet te maken.

België heeft een prescriptieve brandveiligheidwetgeving, alhoewel het mogelijk is om een afwijking aan te vragen gebruikmakende van een vergelijke benadering. De ontwikkeling van het Nieuw-Zeelandse (NZ) PBD framework is onderzocht. De referentie voor het vooropgestelde veiligheidsniveau is bepaald door de prescriptieve wetgeving. Eén van de gewijzigde input parameters in de evolutie van het NZ framework is de voorbereidingstijd. Een enquête werd afgenomen van 194 deelnemers met als resultaat dat deze kortere voorbereidingstijd waarschijnlijk niet toepasbaar is in België. Een casestudy werd uitgevoerd op een compartiment van een hoog gebouw gebruikmakende van het NZ framework en een Belgische vergelijkende benadering. Een hoger veiligheidsniveau werd geëist met de Nieuw-Zeelandse benadering. Een letterlijke overname van het framework voor België zou echter niet de beste keuze zijn.

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1. Introduction

Obtaining an acceptable degree of fire safety in buildings can be achieved using two different routes if it comes down to legislation. The prescriptive approach can be used, where the rules are prescribed line by line with an implicit safety level. On the other hand there is the performance based design (PBD) approach, where the objectives that have to be achieved are explicitly stated first (e.g. life safety). The designer can perform engineering calculations to demonstrate the required safety level is achieved. Typically, countries with a statutory legislation (Belgium, France, etc.) will have a prescriptive type of legislation and countries with a common law system (United Kingdom, Australia, etc.) will lean towards a performance based design approach.

Belgian fire safety legislation is of the prescriptive type: Royal Decree July 7th 1994 [1], however, the demand for a performance based design approach is growing because of the limited possibilities of the prescriptive codes (e.g. limited flexibility in design). This is typically one of the main arguments to develop a legal PBD possibility to meet the fire safety requirements. Currently, it is possible to request a deviation from the prescriptive design to the Ministry of Home Affairs in Belgium, but this is a challenging process. Furthermore, this procedure does not guarantee approval and there are no explicit guidelines for this process. A common approach used in Belgium is the comparative approach, where the PBD design must at least be as safe as a similar prescriptive design. This methodology is used in a case study.

Many countries such as Australia, United Kingdom, New Zealand etc. (Appendix 1) already changed their fire safety regulation allowing PBD. It is interesting to look at how these countries started out with a prescriptive legislation somewhat 20 years ago and developed their regulatory system to allow PBD. Some countries have publications on the process of these changes in regulations. For this research thesis, the focus will be put on New Zealand and Sweden. A literature study revealed that the process in New Zealand is well documented.

The development of the New Zealand PBD framework is investigated. The conclusion of a former research thesis [2] was that the first attempt of generating a robust framework was not successful. However, adaptations could be made resulting in an useable framework. This new framework could be used to evaluate the same case studies that failed before to make conclusions about the adaptations in the framework.

A case study is performed using the Belgian typical methodology and the New Zealand PBD framework is used. The case study considers a typical big compartment in a high-rise building. The goal is to work out a solution for each methodology and compare the different fire safety requirements to comply with the methodology or framework. With this information the possibility for the adoption of the New Zealand PBD framework in Belgium is discussed for this case study.

To be able to fully understand the differences between prescriptive design and PBD in a regulatory system, the influencing factors on performance based design and prescriptive design must be investigated. The suggested influencing factors for performance based design would be the used methodology, input parameters and computational model. For the prescriptive design the biggest influence would be severe accidents. The hypothetical question could be posed if the prescriptive design should still be the reference for required safety level.

Pre-movement time of occupants is generally accepted to be part of the methodology of a PBD when life safety is considered. There are not many publications available on exact numbers on this subject. When however a deterministic PBD analysis is made, these pre-movement times are crucial in the analysis. A survey could be the right tool to get an preliminary idea of how Belgian people react on a fire alarm. In addition, this information can be used to make an assessment on pre-movement times in Belgium and the application in a framework.

2. Prescriptive design versus Performance based design

A design in line with prescriptive regulations or a performance based design (PBD) approach both have their advantages and disadvantages. More information on PBD and how a performance based design is build up can be found in Appendix 2. The advantages of both types of designing become clear when the fact is acknowledged that both methods are still used in countries where both approaches are allowed. For most standard applications the easiest way to achieve compliance is to meet the prescriptive requirements. But having a framework for PBD allows deviations from the sets of rules thus allowing flexibility, engineering creativity, room for innovation, etc. Advantages and disadvantages of both design methods are summarised in Table 1.

	Advantages	**Disadvantages**
Prescriptive legislation	- No difficult calculations required - Easy to evaluate if complied with rule	- Complex structure of rules - Objectives are hidden - Not always cost effective - No room for innovation - Assumption there is only one way to provide the safety level - Difficult or impossible for big complex buildings
Performance based legislation	- Clear goal - Permitting innovation, new knowledge can be used - International - Cost effective - Allows flexibility in design - New technology (e.g. fire suppression systems) - No complex structure of rules	- Difficult to define safety level - Need for education - Difficult to evaluate if complied with goal - Sometimes need for computer modelling

Table 1 Prescriptive legislation versus PBD legislation based on *Literature Review of Performance-Based Fire Codes and Design Enviroment* [3]

The most obvious advantage of a prescriptive legislation is that it is a relative straightforward way to meet the requirements. There is no need for an extensive understanding of scientific engineering calculations and it easy to evaluate whether a design meets the requirements. However, it has become clear that in many cases the prescriptive rules are structured in a complex way with no real transparency to the purpose of each rule. Another point of critique is that the requirements are not always the most cost efficient solutions. It is also clear that there is no room for innovation if there is no deviation possible from the set of rules. Implicitly, the idea of only having one way of achieving a safety level is given. Maybe one of biggest disadvantages of prescriptive legislation would be that buildings that have unique features become problematic when fire safety has to be achieved.

Making a design using the performance based approach has many advantages. First of all it is clear what the goals are, the purposes of what should be achieved. These goals can be internationally accepted which lead to universally accepted goals and objectives. Furthermore, innovation and creativity are tremendous drivers in the performance based approach. Qualified engineers can challenge themselves and the fire safety science to come up with original designs. The application of the newest fire safety techniques can be applied together with new developed passive systems. Moreover, the engineer can try to find the most cost efficient solutions to achieve the required safety level. Finally, it is recognised that the performance based design is not a complex set of requirements, but a transparent method and clear to what has to be achieved.

There are also remarkable drawbacks related to the use of a performance based design. Many of these disadvantages were recognised by countries that wanted to incorporate a performance based methodology in their regulatory system. An import part of doing a performance based design is using scientific facts and engineering methods. This requires a significant amount of knowledge so the need for education is recognised. Not only for the designers it crucial to have sufficient knowledge but also for the party reviewing the design, this being an authority having jurisdiction or a third party. Furthermore the need for computer modelling becomes a standard part of PDB. This introduces all kinds of problems, whether it is the validity of certain software or whether it is full comprehension of software. From what was mentioned above it becomes clear that it is much less straightforward to check whether a performance based design has achieved fire safety if every design is unique.

The most difficult problem is probably quantifying the safety level that has to be achieved. Many engineers accept that the achieved safety level using a performance based design should not be more conservative then the safety level achieved with the prescriptive regulations. One of the problems is input that has to be explicitly quantified in a framework such as performance criteria to be able to have an acceptable design that can be compared with a prescriptive design. Some countries suggest values and methodologies but there is still no universal acceptance. This will be further discussed in the next chapters.

3. Why do we need a Performance Based Design framework?

A relevant question is why there is the need for a performance based design framework. This can be answered fairly easily: the essence of a performance based design is that the engineer has freedom to design a solution. However, too much freedom in the design leads to a variety of achieved levels of safety. This is not what a regulatory systems desires. The need for a framework comes from the regulatory system to have some kind of uniformity in designs.

The SFPE Guide to Performance Based Fire Protection [4] identifies four fundamental goals for fire safety: Life safety for occupants and emergency responders, property protection, continuity of operations and environmental protections. The basis of making a performance based design for life safety is trying to prove that the occupants of a building have enough time to evacuate safely out of a building. The most common technique is to show that required safe egress time (RSET) is smaller than the available safe egress time (ASET), allowing safe egress for building occupants. ASET can be calculated using engineering computational techniques such as computational fluid dynamics (CFD) or zone models. But for all these fire models the input must be decided by the engineer such as design fire scenarios, design fires, yields or species production rates, etc. This is already a fundamental point where a variety of possibilities are created. Secondly, a conclusion must be made based on the results of models when tenable conditions are reached. Therefore, tenability or performance criteria must be defined. Depending on that choice, again there many possible outcomes from very conservative to morally questionable.

Then finally RSET must be calculated, which introduces even bigger uncertainties. RSET is commonly calculated as the sum of detection time, alarm (notification) time, pre-movement time and travel time. Detection time and travel time can be calculated using computational models, but still require quite some input from the engineer. Alarm times and pre-movement times can be found in the literature, but there are limited sources and with big range on the data.

In New Zealand the need for a framework was realised soon after the legislation allowed to design buildings using a performance based design in 1992. The necessary input and acceptance criteria were left up to the designing engineer to decide, only qualitative guidance was given. Afterwards approval for the design was required by the authority having jurisdiction. This lead many times to a wide variation of interpretation and significant differences in the safety levels [5]. A conceptual framework was created and developed into the Verification Method C/VM2 [6], a performance based design methodology. This framework prescribes the necessary input (quantitative). Now a more uniform level of safety should be achieved over the different designs made by different engineers. The evolution of the New Zealand fire safety legislation will be discussed in the next chapters.

In Sweden the legislation changed in 1994 from prescriptive to function-based. The same conclusion was made, where too much freedom lead to greater uncertainty concerning the achieved levels of safety in a fire safety design [8]. Here again, a framework was developed with prescribed quantified input. The evolution of the Swedish fire safety legislation will be discussed in the next chapters and more extensively in Appendix 6.

4. Which input could be prescribed in a PBD framework and how?

In countries like New Zealand and Sweden the need for a framework was a practical necessity that was discovered by the authorities after introducing the possibility for designer to use performance based design [5,8]. It soon became clear that the achieved safety level using a PBD design went from very conservative to barely acceptable. The solution to this problem was clear, the need for a uniform approach and further guidance was recognised. But still some the questions remain.

How should the input be prescribed in a framework? What approach should be used - probabilistic or deterministic?

A probabilistic approach would be preferred to be able to have a representation of the real events [8]. This could be in the form of event trees with designated probabilities. Once enough statistical information is available, a simplification can be made to go from statistical information to deterministic explicit threshold values. This also includes the use of recognised safety factors to be able to design for different safety levels. The fire safety science has however not reached this stadium yet.

First, there is a general lack of available data because of the very nature of fire safety engineering. Representative large-scale test are very expensive and require a lot of effort. Repeating an experiment is also extremely difficult because of destructive character of fire together with the many influencing parameters on the system and sub-systems level. Real big fires are characterised by a low frequency and on sight measurements are practically not done. This makes fire safety engineering unique in the sense that there will always be a very scarce amount of relevant data available.

A second current limiting factor would be computational time for Computational Fluid Dynamics (CFD) simulations. The more detailed a simulation is performed, the more equations that have to solved, the longer it takes a computer to process the calculations. For every change of a parameter a new simulation must be made. In the capitalistic environment where 'time is money' this becomes literally computational expensive.

To conclude would a probabilistic be preferred, but forced by the difficulties mentioned above is a deterministic approach often chosen for a framework.

Comparative approach

A comparative approach using deterministic input is often chosen in Belgium to deviate from the prescriptive fire safety requirements [1]. The comparative approach is a methodology where it has to be proven that an alternative design is at least as safe as the safety level guaranteed with the prescriptive regulations. The alternative design uses a PBD methodology to demonstrate the safety level. A graphical representation of this principle can be found in Fig. 1. There are also stand-alone PBD frameworks like in New Zealand for example which will be further discussed.

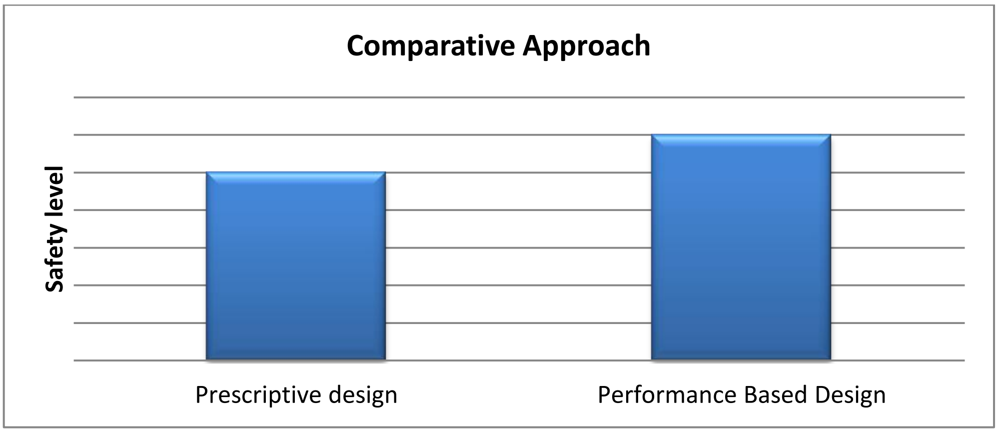


Fig. 1 Comparative approach

Which input should be prescribed?

For a probabilistic approach (e.g. quantified risk analysis) there is a lot statistical information necessary such as probabilities of systems and sub-systems but also interactions between sub-system (e.g. interaction sprinklers and natural ventilation). There is information required about frequency of ignition, distributions of fire growth and available fuels, reliability of fire safety systems, etc. A lot of information is also required about human behaviour such is pre-movement times and reactions of people. Furthermore, evaluation criteria are also required, e.g. acceptable social and individual risk, to make conclusions. This will not be the focus of this thesis.

For a deterministic approach the necessary information for a required safe egress time (RSET) / available safe egress time (ASET) methodology could be further investigated. ASET/RSET analysis is a well recognised methodology where the safety of building occupants is analysed in a fire situation. The available time before untenable conditions can be simulated using modelling software (e.g. CFD or zone models). There is however a lot of information required by the designer to be able to setup the model.

Scenarios must be created and a design fire has to be defined with representative properties. Furthermore, performance criteria have to be established in such a way that an evaluation can be made when untenable conditions are reached. The time before untenable conditions is reached can then be compared to the time it takes for occupants to leave the building. This time is called RSET. RSET is typically defined as the sum of detection time, alarm (notification) time, pre-movement time and travel time. The criteria for movement time and detection time can be calculated but the alarm time and pre-movement time have to be chosen.

When ASET is compared to RSET, a conclusion can be made on whether the occupants can safely leave the building or not. The additional time occupants have before untenable conditions are reached can be defined as safety margin. When a performance based design framework is compared to prescriptive design this safety margin should be bigger than zero for the PBD framework but not exceed excessively this value. This would indicate an equal achieved level of safety between the framework and the prescriptive regulations. When the safety margin wildly exceeds in positive or negative direction, this would indicate respectively a very conservative or unsafe achieved level of safety. The conclusion for both of last frameworks would be that framework is not appropriate to design fire safe buildings.

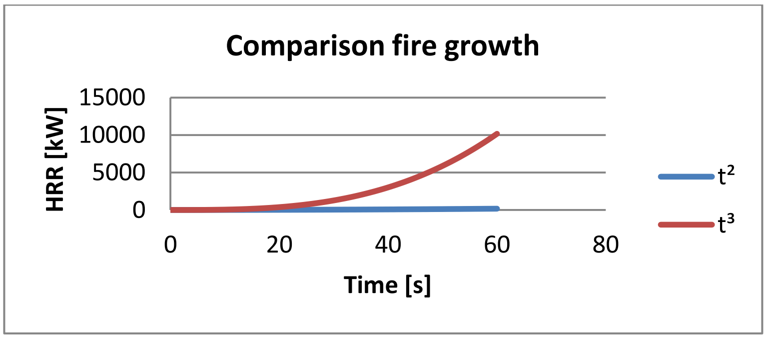
Prescribed input

The prescribed input for a deterministic PBD framework could include:

- Modelling rules
    - Choice of software
    - Leakage through construction parts
    - Maximum temperatures before deformations
    - Maximum temperature for breakage of windows
    - Influence sprinklers on heat release rate
- Design fire characteristics
    - Fire growth rate
    - Peak heat release rate
    - Heat of combustion
    - Fire load energy density
    - Species production: CO, CO_2 , water, soot

- Heat flux
    - Time
    - Radiative fraction
- Movement of people
    - Occupant density
    - Detector criteria: heat detectors, smoke detectors, sprinklers
    - Pre-movement times
    - Travel speeds
- Performance criteria
    - Visibility
    - Thermal (FED or maximal values)
    - Radiative flux
    - Toxicity (FED or concentrations)
    - Thermal effects on structure
    - Fire spread
    - Smoke damage
    - Fire barrier and structural integrity
    - Damage to exposed property and
    - Damage to environment
- Design fire scenarios
    - Worst credible case: typical fire
    - Blocked egress: reduced egress possibilities
    - Robustness: fail of active fire system
    - Smouldering fire: slow developing
    - Fire fighters operations
    - etc.

This begs the question how much of the above mentioned parameters should be prescribed. All of these input parameters will have an impact on the result of analysis. A sensitivity analysis on the influence of these parameters will not be the focus of this thesis. Intuitively it can be suggested that the fire growth rate t^2 or t^3 might be one of the most significant influences. An illustration of this is given in the Graph 1 and Table 2 for a fast growing fire ($\alpha = 0.047\ kW/s^2$).



Graph 1 Comparison fire growth

Time [s]	t^2 [kW]	t^3 [kW]
20	19	376
40	75	3008
60	169	10152

Table 2 Comparison fire growth

Furthermore, many of the input parameters are linked together influencing the final outcome. For example a severe design fire evaluated with relaxed performance criteria could lead to the same conclusion as small fire evaluated with conservative performance criteria. It could be stated that when one or more input parameters are chosen very conservative because of a lack of certainty, it could result in a conservative and therefore unusable framework.

Creating a new framework

A suggested sequence of creating a PBD framework could be done by first defining the input parameters where a lot of data is available. Afterwards the parameters with more uncertainty should be chosen in such a way that the same level of safety is achieved as in a design according to the prescriptive regulations. The choice of input parameters will be influenced by the local culture and habits. For example could performance criteria be more relaxed when a sprinkler system is used or pre-movement times could become longer or shorter depending on the local perception of risk of people.

Design fire

One of the biggest problems is how to chose a design fire. Should it depend on the current situation or a generic fire be chosen. Looking at the current situation, the furniture and other fuel present, this would indeed give a good idea of how a fire would like right now. However, buildings have a lifespan that is longer than typical furniture. For example apartments built in the '70 are still very frequently found but have now probably a new generation of occupants. The current furniture has probably a lot more plastics and other synthetics in it. So a specific design made in the '70 based on the fuel available back then would not entirely represent the current situation. So the choice of a generic fire with prescribed input would become justifiable in a PBD framework. But is this a good evolution? This will be further discussed in the next chapters.

Now these input parameters can be chosen, for example heat release rate, yields for species, etc. In this step very conservative values can be chosen for big toxic fires or data for less polluting fires is available as well.

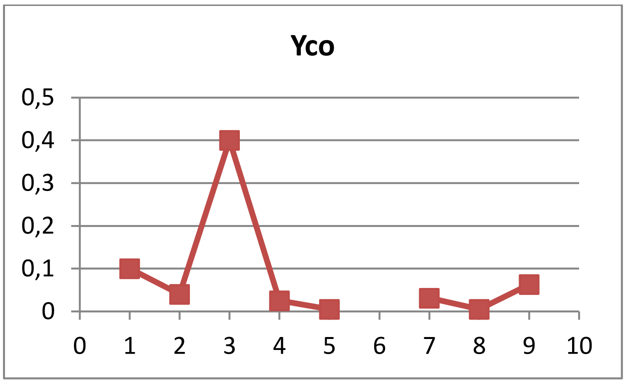
Combustion yields

Typical examples of input parameters are combustion yields. If the yields for different species would be further investigated one would found quite a big spread on the available data. The values in Table 3 come from PBD frameworks or from materials that can frequently be found as combustible construction materials. This list is far for complete but gives an idea on the spread of the available data.

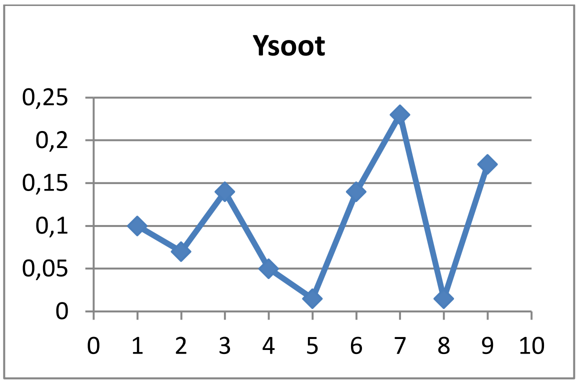
		$Y_{soot}\left[\frac{g}{g}\right]$	$Y_{CO}\left[\frac{g}{g}\right]$	$Y_{CO_2}\left[\frac{g}{g}\right]$
1. Probable worst case fire PBD framework **Sweden** BBRAD [9]		0.10	0.10	2.50
Design fire PBD framework **New Zealand** C/VM2 [6], design fire in for all buildings (stack height less than 3m)	**2. Pre-flashover**	0.07	0.04	1.50
	3. Post-flashover	0.14	0.40	1.50
4.Design fire Weighted average representative design fires based on the results of the Delphi study [10]		0.05	0.025	1.40
Wood fuel SFPE Handbook of Fire protection Engineering [11]	**5. Well-ventilated**	0.015	0.005	1.33
	6. Ventilation-controlled	0.14	N/A	N/A
7. Polyurethane (flexible) fuel SFPE Handbook of Fire protection Engineering [11]	**Well-ventilated**	0.23	0.031	1.5
8. Wood (Red oak) fuel SFPE Handbook of Fire protection Engineering [12]	**Well-ventilated**	0.015	0.005	1.27
9. PVC SFPE Handbook of Fire protection Engineering [12]	**Well-ventilated**	0.172	0.063	0.46

Table 3 Combustion yields [6, 9, 10, 11, 12]

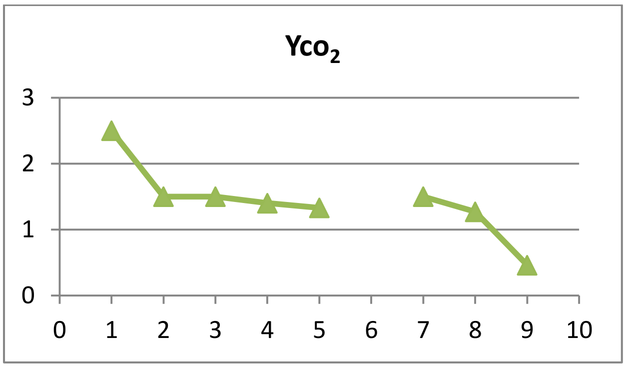
The purpose of the Graph 2 to 4 is to illustrate the spread on the data for typical products that can be found in buildings. The number on the x-axis correspond with the fuels in the Table 3. It is clear that the values chosen in the PBD frameworks for Sweden and New Zealand are somewhere in the middle of the given values and therefore are good representative values. The peak in the CO yield in Graph 2 is a value for post-flashover conditions, so is in that sense still reasonable to have a high value.



Graph 2 CO yield



Graph 3 Soot yield



Graph 4 CO2 yield

The ratio

It is difficult to make an evaluation on whether input values are conservative if the performance criteria are not known. If the performance criteria would be chosen conservative as well, then the entire framework might become too conservative. In other words if the performance criteria are prescribed, the design fire should also be prescribed to end up with consistent design in terms of safety level. So there must be a relative balance between severity of the design fire and performance criteria that are used to evaluate whether untenable conditions are reached. This could be in the form of a ratio based on two parameters each given a weight using Table 4.

Design fire		Performance criteria	
1	Severe	1	Relaxed
2	Moderate	2	Moderate
3	Mild	3	Conservative

Table 4 Weights for the ratio

$$\frac{Relaxed\ performance\ criteria}{Severe\ fire} = \frac{1}{1} = 1 \qquad (4.1)$$

$$\frac{Conservative\ performance\ criteria}{Mild\ fire} = \frac{3}{3} = 1 \qquad (4.2)$$

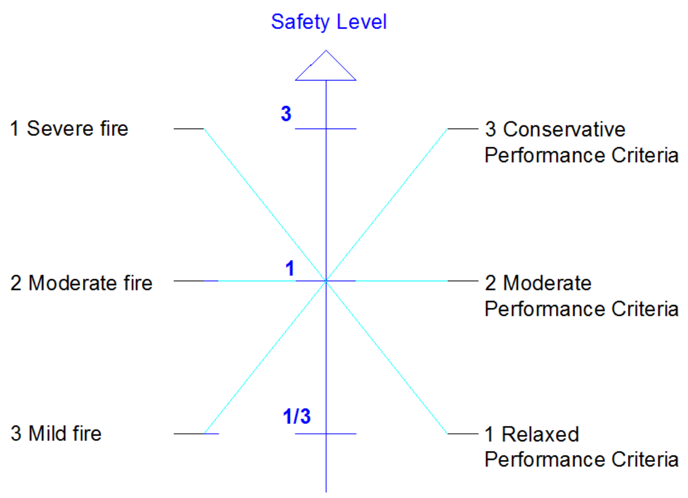


Fig. 2 The ratio, safety level 1

As illustrated in the equations (4.1), (4.2) and Fig. 2 the ratio would theoretically become equal to one as the safety level would be reached. Using this methodology there would be the option to chose between different types of fires depending on the fuel present in the building. When buildings would need a higher level of safety because of the specific use of the building (e.g. big football stadium) then a ratio bigger than one could be prescribed (Fig. 3) :

$$\frac{Conservative\ performance\ criteria}{Severe\ fire} = \frac{3}{1} = 3 \qquad (4.3)$$

Or an unsafe design would reflect in ratio smaller than one (Fig. 3):

$$\frac{Relaxed\ performance\ criteria}{Mild\ fire} = \frac{1}{3} \qquad (4.4)$$

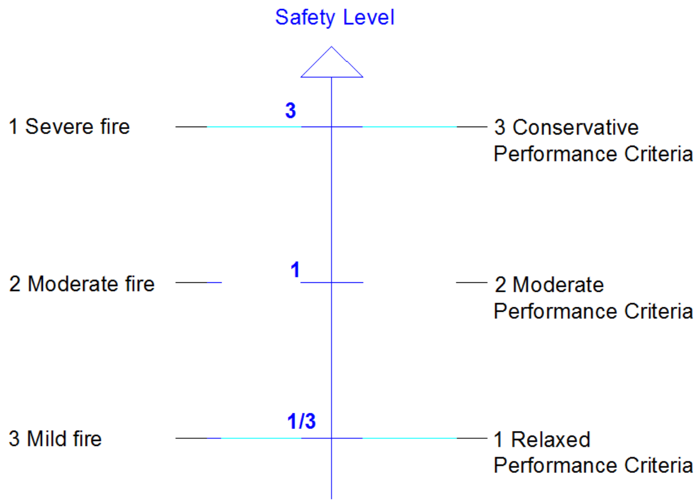


Fig. 3 The ratio, different safety levels

The ratio could be defined as some sort of required safety level. If only one value for each input parameter is prescribed for the design fire then the PBD loses its flexibility in design. The next step is to quantify the parameters from Table 4.

Human behaviour

The input for the human behaviour then also could be prescribed. Again the literature ranges from very conservative to unsafe choices. The choice for the pre-movement times is important because of the big impact on the safety margin as will be illustrated further with the evaluation of previous case studies.

Design scenarios

Design scenarios should be prescribed up to some level. But as every building has unique features, it is the moral duty of the designer to include all credible relevant scenarios. There is always the possibility that a scenario is not included because it was not prescribed in some way. It would be a bad evolution to prescribe scenarios to detailed in a performance based design.

Conclusion

In an ideal world distributions would be known for all of the input parameters together with statistical information on fire events. Then it would become possible to identify a characteristic value just like in other engineering sciences. And then afterwards safety factors could be applied on the characteristic values to create design values. These design values are then values that can be used in further calculations.

However, fire safety science is not in this stage yet. A deterministic analysis is often the only realistic choice to make a PBD framework. Many parameters influence each other in such an ASET/RSET - analysis. This is why a ratio was suggested to make this relation explicit and introduce more flexibility in the framework again for the designer.

5. New Zealand

5.1. History fire safety legislation

The fire safety legislation of New Zealand was before 1992 a pure prescriptive legislation. A new Building Act [13] was put in place in December 1991, which would change the fire safety engineering in New Zealand drastically. This new act would replace the existing fire safety code NZ Standard 1900, Chapter 5 [14] and would allow performance based design (PBD). The primary goals of the Building Act 1991 concern the health and safety of the building occupants, structural stability, access and safety of occupants, services and facilities. Secondary goals are prevention of fire spread, energy efficiency and fire fighter access [15].

The 1991 Act required that all new buildings must be constructed according to the New Zealand Building Code (NZBC) [16] and established the Building Industry Authority (BIA). The New Zealand Building Code can be found in the first schedule of the New Zealand Building Regulations [17]. The fire safety requirements in the NZBC consisted of 4 clauses C1 to C4, Table 5 . The current clauses C1 to C6 [18] are also shown in this table.

From 1992		**From 10 April 2012**	
C1	Outbreak of fire	C1	Protection from fire
C2	Means of escape	C2	Prevention of fire occurring
C3	Spread of fire	C3	Fire Effecting areas beyond the fire source
C4	Structural stability	C4	Movement to a place of safety
		C5	Access and safety for firefighting operations
		C6	Structural stability

Table 5 Comparison clauses NZBC

When this legislation first came in effect some problems surfaced [15]. There were no approved Verification Methods (framework for PBD) and Acceptable Solutions (prescriptive solution) available to fulfil the fire safety requirements from the NZBC. The BIA created a new Acceptable Solution(AS) [19] which would be significantly better than the previous prescriptive fire legislation. The acceptable solution developed further into '*Approved Document for New Zealand Building Code Fire Safety Clauses C1, C2, C3, C4 C/AS1 Fire safety*' [20], or better known as C/AS1. However, the development of an approved performance based design framework that could be used in the Verification Method (VM) would soon seem to be a complex task.

On November 30th 2004 the new Building Act 2004 [21] was passed into law to improve building controls and building practices. This act replaced the Building Act 1991 [13] and dissolved the BIA. Before 2004 there were some significant systematic failures in the building control process. The main purpose of the act was to make sure that the buildings are designed and build correctly from the first time. There were also some conflicts between the Fire Service Act and the Building Act 1991 that had to be resolved [22]. The Building Act 2004 also created the Department of Building and Housing (DBH), which would that take care of the administration of the new Building Act. The Building Act 2004 [21] has now four major goals:

- *People can use buildings safely without endangering their health.*
- *Buildings have attributes that contribute appropriately to the health, physical independence and wellbeing of the people who use them.*
- *People who use a building can escape from the building if it is on fire.*
- *Buildings are designed, constructed and able to be used in ways that promote sustainable development.*

A schematic overview of the New Zealand regulatory framework for fire safety in buildings can be found in Fig. 4. The '*approved document C/AS1*' falls under Acceptable Solution and the '*alternative design*' is now not commonly used anymore, but the Verification Method (marked in green) is used instead. These are different ways that can be used to comply with the fire safety regulations from the Building Code [18]. The Acceptable solution is a prescriptive way of achieving the requirements of the code. The Verification Method is the performance based design method to achieve the requirements. The first version of C/VM2 [6] was published in 2012 and developed further into what it is today.

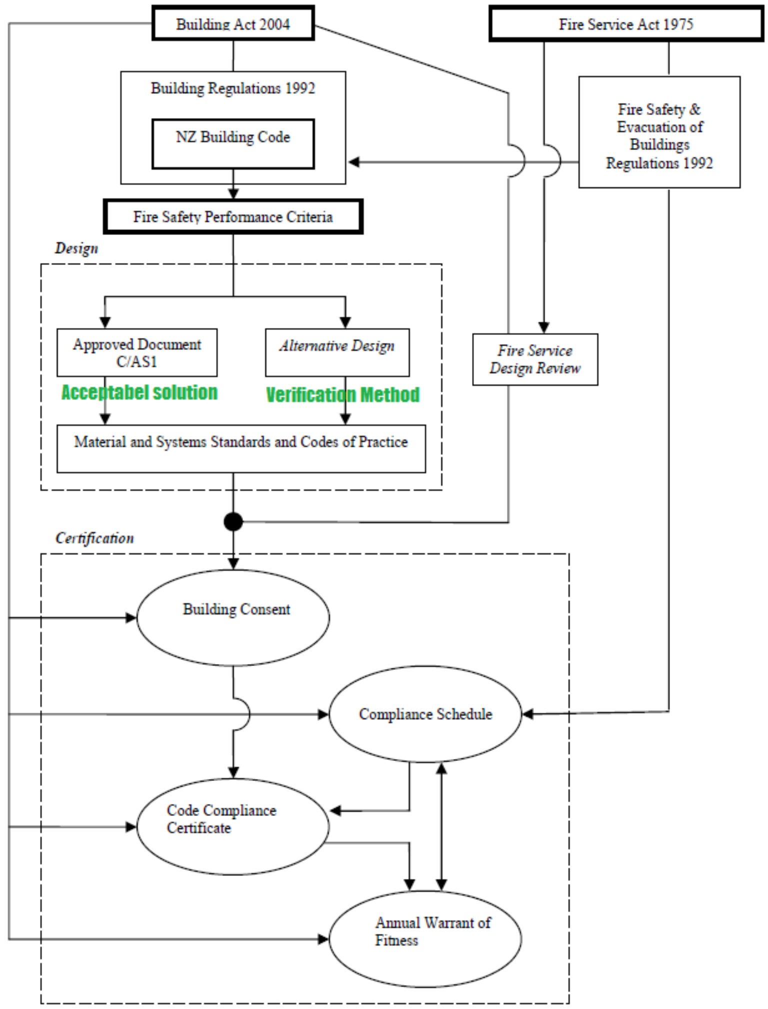


Fig. 4 New Zealand regulatory framework for fire safety in buildings from ***Apparent Level of Safety in Buildings Meeting the New Zealand Building Code Approved Document C/AS1 - Fire Safety*** **[2]**

5.2. Development of Performance Based Design framework

5.2.1. Design Guide

The first draft for a performance based design framework was produced by a Study Group consisting of the New Zealand Structural Engineering Society and the New Zealand Fire Protection Association. They managed to produce a Design Guide [15] for performance based design fire safety engineering for buildings. The objective of the Design Guide was to give guidance to engineers making a performance based design using the New Zealand Building Code [17]. The Design Guide is qualitative, so the need for quantifiable performance based fire codes was getting recognised. Most of the design inputs where still very much prone to a subjective engineering judgement (e.g. pre-movement times). According to the Design Guide [15], the engineer can judge if the building is considered to have an acceptable performance illustrated by the following passage:

1. *The design of the building and the activities within the building not present an <u>unreasonable probability</u> of fire occurring, and*
2. *in the event of a fire, the following can be achieved with a <u>reasonable degree of certainty</u>:*
    a. *all occupants will have <u>adequate time</u> to escape to a safe place without being overcome by the effects of the fire;*
    b. *the Fire service will have <u>adequate time</u> and <u>suitable access</u> to undertake rescue operations and to protect property;*
    c. *the fire will not spread to other firecells within an <u>acceptable time</u>;*
    d. *the fire will not spread to adjacent household units and other property;*
    e. *<u>significant quantities</u> of hazardous substances will not be released to the environment;*
    f. *the contents of the building will <u>not be seriously damaged</u>;*
    g. *the building itself will <u>not be seriously damaged</u>;*
    h. *any damage to the building will be <u>easily repairable</u>.*

In the Fire Engineering analysis some type of a worst credible design fire and design scenario have to be considered. An analysis has to be performed to test if an acceptable performance is reached. It is interesting to already point out that there are some remarkable assumptions made, for example sprinklers are assumed to always work and always limit the fire size.

5.2.2. 2008 conceptual framework

Since august 2006, a first conceptual framework for performance based design was being developed by the Department of Building and Housing (DBH). This PBD framework would become mandatory to comply with the New Zealand Building Code (NZBC) if it was to be adopted. There are however at that time two ways to comply with the NZBC, the choice is up to the designer. The prescriptive Compliance Document C/AS1 could be used or a performance based design could be made. The DBH was of the opinion that the PBD conceptual framework should have the same level of fire safety as the prescriptive C/AS1. So a research thesis [2] analysed 12 buildings, that comply with C/AS1, using the first conceptual framework developed by the DBH. The result of the research thesis showed that conceptual PBD framework was too conservative because none of the buildings that comply with C/AS1 would pass the proposed criteria for life safety in the PBD conceptual framework. It was concluded that the proposed conceptual framework was not ready yet to become mandatory.

5.2.3. 2011 conceptual framework

Two thesis's were made to investigate the conceptual framework in 2011. One research thesis [24] would investigate the conceptual PBD framework against the existing current prescriptive legislation, New Zealand Compliance Document C/AS1 [25]. And in another research thesis [26] would the conceptual PBD framework be investigated against the international building code (prescriptive), NFPA 5000 Building Construction and Safety Code [27]. Both thesis's showed that the PBD conceptual framework give a robust and consistent methodology. They both agree in general that safety level with the prescriptive legislations is achieved while using the conceptual framework.

5.2.4. Verification method C/VM2

Finally, April 12th 2012 the verification method C/VM2 [6] is published. It gives a means of compliance with the New Zealand Building Code Clauses C1-C6 Protection from Fire [17]. Since the publication there were 4 amendments, the latest amendment is effective from July 1st 2014.

5.3. Changes in Design Scenarios

This first evaluated conceptual framework (2008) consisted of eight design fire scenarios which are very similar to the scenarios suggested in the NFPA's life safety code 101 [28]. Two more scenarios were introduced in the conceptual framework in 2011 [5]: Fire fighting operation and Robustness check. A list of the scenarios can be found in the table in Appendix 4. In the final PBD framework C/VM2 the same scenarios are used as the 2011 framework, but in a different order. The objective of these different scenarios is to cover the different events that can occur. The conclusion can be made that most of these scenarios are very similar in the different frameworks. It is however interesting to see that the NFPA tries to include some kind of risk using probability and consequences in the additional scenarios.

The approach of the International Organisation of Standardization (ISO) [29] would be different: the choice of scenarios should be based on risk in this methodology. For each fire safety objective should the scenario be considered with the highest rank. This will not further be discussed.

The basis for selecting design scenarios are summarised in [30] presented first in [31]. The statements are very generic, yet point out interesting aspects:

- *The assembly of scenarios must cover the **risks** that we wish to protect against.*
- *The scenarios must be **sufficiently detailed** to illustrate the variety of each class of hazardous situations. It is important to illustrate the variety of directions that an event could take and the possibility of active and passive safety measures to influence development.*
- *The scenarios must be **perceived as realistic**. This means that the sequences of events must be logical and sensible, thereby increasing motivation and confidence among the decision makers, such as owners, users, and authorities. Realistic in this sense does not necessarily imply probable in relation to the calculated risk from a risk analysis.*
- *The scenarios must be **easy to understand**. A complex scenario could easily divert attention from important areas.*
- *The scenarios must be **dynamic** in the sense that new experience and knowledge can be used.*
- *The scenarios should be adapted to the **specific system** considered.*
- *The scenarios should be **logically consistent** in the sense that they should not result in biased or unreasonable requirements for some enterprises and systems.*
- *The scenarios should be general in the sense that they should **not favour specific safety** measures.*
- *Assessment of the scenarios should contribute to **decision support** in matters related to fire safety.*

5.4. Reasons of failure in 2008 Framework

The main reasons why the 12 buildings fail in the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2] using the prescriptive Acceptable Solution C/AS1 to evaluate the conceptual framework 2008 will be presented here. Only the life safety objective will be considered in these reasons. A comparison will be made with the conceptual framework 2011 and/or the current PBD framework, Verification Method C/VM2.

The adaptations that are made to the 2008 conceptual framework are:

- Pre-movement time adaption
- Not applicable scenarios
- ASET in room of fire origin left out
- Performance criteria relaxed
- Reduced fire size

5.4.1. Pre-movement time

There are very limited publications about this subject and therefore it needs more research. There is an important publication that gives pre-movement times in the British Standard PD 7974-6:2004 [32]. These times are used in the conceptual framework 2008. These pre-movement times are quite conservative. In the later version of the conceptual framework and in the final Verification Method C/VM2 these times are in general shorter. These pre-movement times can be correctly assumed to be shorter because of the widespread culture of evacuating buildings when the fire alarm sounds [5]. The short pre-movement times are based on the most optimistic values from British Standard PD 7974-6 and were further validated in a sensitivity study [33].

In Table 6 the influence on the total RSET times of shorter pre-movement times is showed on 6 of the case studies from the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2]. These 6 case studies are chosen because they cover most combinations of sleeping or awake occupancy and familiarity with the building.

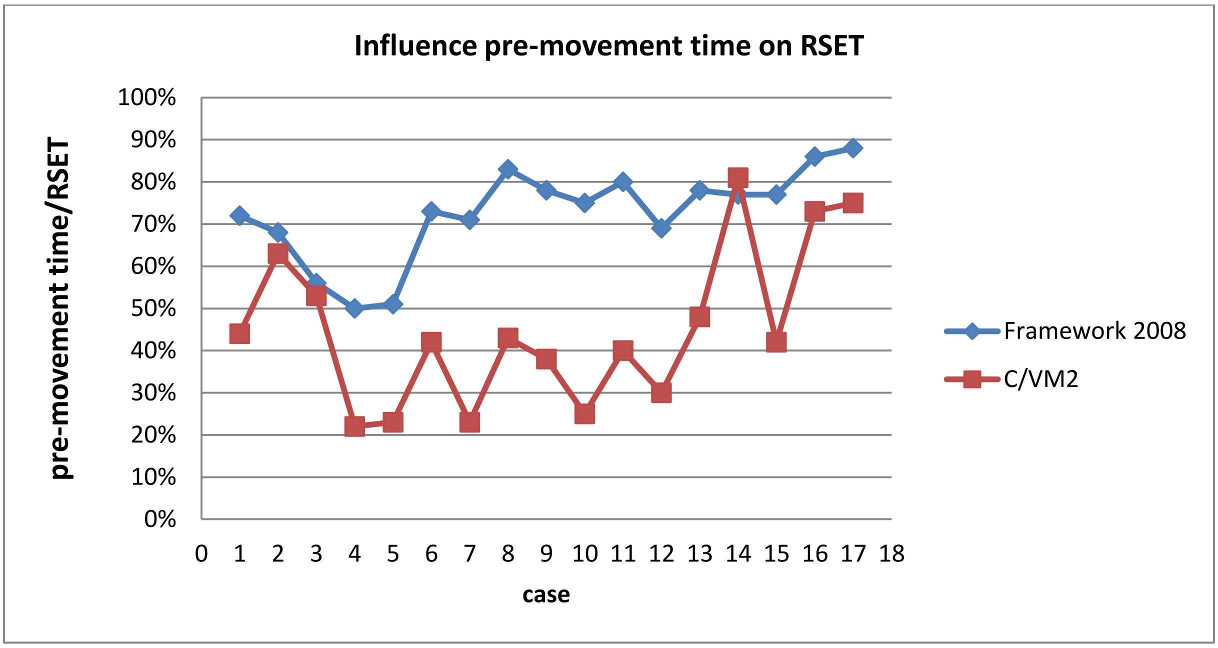
In general it was found that the pre-movement time dominates the RSET with an average share of 72% on the total RSET in the research thesis using the 2008 conceptual framework. Now the pre-movement times are taken from the C/VM2 method and applied on the same case studies. The difference between the two sets of pre-movement times becomes very clear. The influence of the pre-movement times is significantly lower with an average of 45% in Verification Method C/VM2 (marked in green). The Verification Method stays however conservative on pre-movement times when people are asleep (marked in red).

$\frac{pre-movement\ time}{total\ RSET}$	Room of origin		Other room		Entire building	
	Framework 2008	C/VM2	Framework 2008	C/VM2	Framework 2008	C/VM2
Case 1: Apartments Asleep and familiar	$\frac{120}{166} = 72\ \%$	$\frac{60}{136} = 44\%$	$\frac{300}{444} = 68\%$	$\frac{300}{474} = 63\%$	$\frac{300}{537} = 66\%$	$\frac{300}{567} = 66\%$
Case 2 : Sport and recreation building Awake and unfamiliar	$\frac{180}{363} = 50\%$	$\frac{60}{273} = 22\%$	$\frac{180}{355} = 51\%$	$\frac{60}{265} = 23\%$	$\frac{360}{494} = 73\%$	$\frac{120}{284} = 42\%$
Case 3: Warehouse and offices Awake and familiar	$\frac{180}{253} = 71\%$	$\frac{30}{133} = 23\%$	$\frac{240}{288} = 83\%$	$\frac{60}{138} = 43\%$	$\frac{240}{306} = 78\%$	$\frac{60}{156} = 38\%$
Case 4: Office Awake and familiar	$\frac{180}{239} = 75\%$	$\frac{30}{119} = 25\%$	$\frac{240}{300} = 80\%$	$\frac{60}{150} = 40\%$	$\frac{240}{350} = 69\%$	$\frac{60}{200} = 30\%$
Case 6: Motel Asleep and unfamiliar	$\frac{120}{154} = 78\%$	$\frac{60}{124} = 48\%$	N/A	N/A	$\frac{360}{468} = 77\%$	$\frac{600}{738} = 81\%$
Case 9: Retirement home Asleep and familiar	$\frac{180}{243} = 77\%$	$\frac{60}{144} = 42\%$	$\frac{480}{560} = 86\%$	$\frac{300}{410} = 73\%$	$\frac{480}{548} = 88\%$	$\frac{300}{398} = 75\%$

Table 6 Influence of pre-movement times on RSET

More detailed numbers and pie charts that illustrate the influence of each pre-movement time on the total RSET can be found in Appendix 8.

A first conclusion based on these numbers can be made about difference in influences between the 2008 framework and the current C/VM2 framework. On average the pre-movement times have 27% less influence on the RSET in the current C/VM2 framework. This is also showed in Graph 5 and Table 7. The upper set of data (blue) gives the influence of the pre-movement times on RSET for the 2008 framework. The lower set of data (red) gives the same information for the C/VM2 method. It is showed that C/VM2 line is always under or on the framework 2008 line accept for one scenario. In this last configuration the people are asleep and unfamiliar with the building. This illustrates that the new C/VM2 framework is more conservative with pre-movement time only in this configuration.



Graph 5 Influence pre-movement time on RSET

	Room of origin	Other room	Entire building
case 1	1	2	3
case 2	4	5	6
case 3	7	8	9
case 4	10	11	12
case 6	13	N/A	14
case 9	15	16	17

Table 7 Case numbers

A second conclusion that can be made is that the pre-movement times have a big influence on the total RSET time in general. This is remarkable because it is an input parameter that only has very few recognised publications.

It has to be noted that in the new C/VM2 framework a notification time of 30 seconds for the time between detection and actual alarm is introduced in the calculation for RSET. On average this represents an influence of 15% on the total RSET and therefore does not compensate the shorter pre-movement times. This conclusion is also based on the table in Appendix 8.

5.4.2. Not applicable scenarios

Table 8 shows the evolutions of some design scenarios with regard to when they are applicable. The evolution is very clear, the design scenarios become easier to pass because they are not always required to be performed any more. The intent is probably that only buildings with more occupants need a more thorough investigation because they require a higher level of safety. The influence of sprinklers can here already be noticed in the blocked egress scenario. For vertical egress (e.g. staircases) in a sprinklered building, these escape routes are allowed to serve as many as 250 occupants without having to do any calculations to see if the scenario would pass instead of 150 occupants without a sprinkler system. This shows that the Verification Method has much confidence in the reliability of sprinklers and therefore the requirements can be relaxed. The confidence of sprinklers is very clear in C/VM2.

	Conceptual framework 2008	**Conceptual framework 2011**	**C/VM2 (2014)**
Scenario 2: blocked egress	Escape route serves more than **50 occupants.**	**Horizontal** escape route serves more than **50 occupants**, **vertical** route serves more than **150 occupants, 250 occupants** if sprinklered.	**Horizontal** escape route serves more than **50 occupants**, **vertical** route serves more than **150 occupants, 250 occupants** if sprinklered.
Scenario 3: unoccupied spaces	More than **50 occupants** in room.	More than **50 occupants** in room.	More than **50 occupants** in room with **manual alarm** system, **150 occupants** with **automatic detection and alarm.**
Scenario 4: concealed spaces	More than **50 occupants** in room.	More than **50 people** in room and only if concealed space has **combustibles** and is more than **0.8m deep.**	More than **50 occupants** in room and only if concealed space has **combustibles (other than timber framing**) and is more than **0.8m deep.**

Table 8 Evolution occupants and scenarios

An example using Table 8: Blocked egress scenario in *case building 4: offices* in the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2].

> If the current Verification Method C/VM2 would be applied, then this scenario would automatically pass because there are only 78 occupants using the stairs. Stairs are allowed to serve 150 occupants without having to perform calculations in the

scenario in C/VM2. In the 2008 conceptual framework the scenario would have to be checked.

5.4.3. ASET room of fire origin

Another interesting change in the frameworks is for the room of fire origin in the challenging fire scenario. Since ASET/RSET analysis would be prescribed in the framework, it would become very difficult to pass the performance criteria in a normal sized room (e.g. an apartment) where the fire starts. Tenability criteria (visibility criterion) would be reached very fast, before people would be outside the room. This is also confirmed in the first case in the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2].

In the Verification Method C/VM2, ASET does not need to be determined if the room of fire origin has a total floor area of less than 500m², more than one direction of travel or a single direction of travel less then 25m and an occupant load of less than 150 people for the room or 100 people for intermediate floors. If all of these requirements are fulfilled, which they are for most normal sized buildings, then ASET only needs to be determined for occupants outside the room of fire origin.

5.4.4. Performance criteria

The conceptual framework 2008 has two set of performance criteria for life safety: simple criteria and detailed criteria. The simple criteria are based on the principal where the occupants do not come in contact with the smoke at all: the smoke layer must stay 2.5m above the floor and the upper layer temperature can maximal be 200°C. These criteria can only in seldom cases be used. Therefore the detailed criteria are very important. The detailed criteria are a set of 3 parameters that cannot be exceeded 2m above floor level:

- $FED_{co} \leq 0.3$
- $FED_{thermal} \leq 0.3$
- Visibility > 5m in rooms up to 100m² or Visibility > 10 m in rooms bigger than 100m²

In the Verification Method C/VM2 the same criteria can be found in Clause C4.3 [18] with a very important difference described in Clause C4.4. Here it stated that $FED_{thermal}$ and visibility does not need to be considered if it is not possible to expose more than 1000 occupants in a firecell that is sprinkler protected. So for most buildings that are equipped with a sprinkler system an ASET calculation will only be performed using the carbon monoxide criterion. This is very important because the visibility criterion is always in normal circumstances reached much sooner than the fractional effective dose criterion for toxic gasses. This means that it would become easier to achieve a pass for a building because of the relaxed performance criteria.

5.4.5. Fire size development storage activities

In the conceptual framework 2008 the fire growth for storage activities is always of the type t^3. This is an extremely fast developing fire. The fire growth rate (α) can be calculated in function of the stacking height. In the Verification Method C/VM2 it is only when stacking height is more than 5m that a t^3-fire is used. If the stacking height is less than 5 meters a t^2 type fire is used. This means that the fires in the Verification Method develop slower for storages with a stack height lower then 5m. Stacking heights of less than 5 m are very common (e.g. supermarket), so for these places the framework became more relaxed.

5.5. Case studies re-evaluated

If 6 of the case studies from the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2] would be re-evaluated for life safety based on a ASET/RSET analysis using the C/VM2 framework, some interesting remarks can be made. A detailed overview is given of the ASET/ RSET and safety margins for the 6 scenarios in Appendix 8. Only the information that is available in the research thesis can be worked with, so there is some information missing but nevertheless enough is available to make some remarkable points.

Case study 1 fails the scenarios in the research thesis because a negative safety margin is calculated after an ASET/RSET analysis. C/VM2 would allow shorter pre-movement times reducing the RSET. Because of the sprinklers only the FED_{CO} criterion is used in the evaluation in the new framework but this still leads to a small negative safety margin in the room of origin. The FED_{CO} criterion typically is only reached quite some time after the visibility criterion in reached. But this room is excluded from the ASET/RSET analysis in the new C/VM2 framework because of the small surface area (< 500m²). So the scenario would pass for the room of origin. There is not enough information available for the other rooms and entire building to make a conclusion.

Case study 2 also fails the scenarios in the research thesis because a negative safety margin is calculated after an ASET/RSET analysis. If the C/VM2 is used, the shorter pre-movement times and relaxed performance criteria because of the sprinklers result in a positive safety margin for the room of origin and other room. This means that scenarios would pass according to the new framework. There is not enough information available for entire building to make a conclusion.

Case study 3 and 4 also fail the scenarios in the research thesis because big negative safety margins are calculated after an ASET/RSET analysis. These designs have no sprinkler systems but only using the shorter pre-movement times the scenarios pass based on the visibility criterion for the other room and barely still fail for the room of origin. There is not enough information available for entire building to make conclusions.

Case study 6 and 9 also fail the scenarios in the research thesis because negative safety margins are calculated after an ASET/RSET analysis. These designs have no sprinkler systems, so the relaxed performance criteria cannot be used. This results in a negative safety margin in the new framework for the room of origin. However, these rooms of origin can be exempted from the ASET/RSET analysis because of the limited surface area (<500m^2). So the scenarios pass the C/VM2 framework. There is not enough information available for the other rooms and entire building to make conclusions.

5.6. Conclusions about changes in framework

The changes presented in the previous parts: pre-movement time, not applicable scenarios, ASET in room of fire origin, performance criteria and fire size, make the framework less conservative and easier to comply with. This was of course the intent of these changes because the research thesis *Evaluation of the Conceptual Framework for Performance Based Fire Engineering Design in New Zealand* [2] showed that none of case studies would pass if the conceptual framework would be applied on buildings that apply with the prescriptive legislation C/AS1. Since a similar level of safety for both approaches was demanded, the outcomes of the research thesis showed that the conceptual framework was not ready for adoption yet.

One of the introduced changes is the relaxed performance criteria when the building is equipped with a sprinkler system. It can be concluded that is it remarkable easier to comply with the requirements when a sprinkler system is already in the basis of the design. In other words, it would require much more effort to show that a building can pass the fire safety requirements if the choice is made for a heat and smoke control system instead of a sprinkler system. This is confirmed again in the Robustness check (design scenario 10 in C/VM2) where the sprinkler system and automatic fire alarms are exempted from robustness scenario. The scenario does not have to checked with one of those systems failing.

This preference for the use of sprinkler systems goes somewhat against the preferred methodology in developing design scenarios: *The scenarios should be general in the sense that they should not favour specific safety measures* [30]. The confidence in sprinkler systems can probably be justified by the higher experience and reliability of sprinklers for this culture.

A conceptual framework was tested again in 2011 on 4 complex buildings in a research thesis *Evaluating the DBH verification Method to Complex Buildings Designed According to New Zealand Compliance Documents C/AS1* [24] where it became clear that the changes gave a successful outcome when comparing the safety levels produced by both performance based and prescriptive methods. However, the author of the research thesis also concluded that some of the benefits of the performance based designs is having flexibility and allowing innovations, so the question becomes how detailed the PBDs should become prescribed. The freedom of the designer should not be limited by the performance based design framework. So it is suggested that only a deterministic method might not be the best choice and that risk based concept is suggested to be incorporated in a new version of the C/VM2.

Some remarks could be made about the changes in the framework on the advantages of using a PBD above a prescriptive regulation. The goals in the new framework are still stay very clear. But the encouragement of innovation is less clear: input for design is prescribed, sprinklers systems are the easier option to use in design, etc. Because of the increase of rules in the framework the international character of the framework reduces as well. Furthermore, there was no proof found that a PBD using the C/VM2 framework is the more cost effective solutions. Flexibility is also more limited because of the increasing amount of prescriptive rules. And finally, more rules also increase the complexity of the framework.

It can be concluded that none of the advantages of PBD are completely lost, but the advantages are somewhat reduced or less clear in this type of prescriptive PBD framework. Maybe this is the price that has to be paid for a robust performance based framework.

6. Sweden

In 1994 the regulations [34] changed from prescriptive to function-based design in Sweden. Revision of 1994 regulations started in 2006. A pre-study [7] was issued by Boverket, this is the Swedish National Board of Housing, Building and Planning. The objective of this pre-study was to make new regulations that comply with the Planning and Building Act (PBL) [36] and the Planning and Building Ordinance (PBF)[37].

The result of the pre-study had a big impact. The performance based fire regulations changed and acceptable level of safety was now explicit defined in the new regulations of 2012 [38]. Compliance with the Building Regulation BBR [38] can be achieved by either using the prescriptive design or by doing an analytical design (performance based design).

Guidance for the performance based design method is made available by Boverket through general recommendations with a document named BBRAD [9]. This document for the analytical design is already in its third edition, but had only few adaption's since the introduction in 2012. The difference with New Zealand in the evolution of the framework is that there were no research thesis's found that investigated the frameworks that were under development. More information about the Swedish fire safety legislation can be found in Appendix 6.

The conclusion based on a case study [10] was that the design fires are less conservative in the performance based design framework from 2012 than was previously observed when there was no framework available. This was mainly based on the relative low soot production yields prescribed in the new framework. The difference between design fires and real life fires was also studied using a statistical analysis. One of the conclusions was here again that the design fires are less conservative then the design fires that were chosen when there was no prescribed input. But at the same time it was found that automatic extinguish systems were treated to conservatively before the recommended framework was available. It is shown in full-scale sprinkler test that the new fire safety approach better corresponds with reality concerning fire development [39]. In general it was found that the new framework might result in a higher fire risk.

From the same case study [10] it is concluded that the new recommended guidelines create much more consistency in performance based designs. The remark is made that the choice of an automatic extinguish systems has a big influence on the results in the framework. This will probably result in more designs using active fire protection systems. But it is also recognised that there is still a need for more scientific values for the prescribed input.

A Swedish study [40] from Lund University compared the prescriptive design method to the 2012 PBD design method. The conclusion was made that there is a difference in achieved safety level between the two methods. The analytical method (PBD) gave more conservative results compared to the prescriptive method. It was also concluded again that there is less uncertainty to comply with mandatory regulations then before the introduction of the framework.

The goal is to go more towards a probabilistic methodology [8], but the performance criteria for these types of working methods are not available yet. Therefore the defined performance criteria are only given in a deterministic way for now. A probabilistic risk based verification method can give important insights when decisions have to be made [35]. There is also guidance for alterations or extensions to existing buildings since the 2012 fire safety regulations.

7. Differences in framework New Zealand and Sweden

Some of the remarkable differences between the two performance based frameworks from New Zealand (C/VM2) [6] and Sweden (BBRAD) [9] are presented in Table 9. Some of these differences may result in different designs. But both frameworks result in an achieved level of safety comparable to their respective prescriptive legislation as mentioned before.

	New Zealand: C/VM2 [6]	**Sweden: BBRAD [9]**
Type	- Deterministic (quantitative)	- Probabilistic (limited guidance) - Deterministic (quantitative)
Responsibility verification	- Authority having jurisdiction - peer review third party - Final approval by competent person	- Designer
PBD framework	Mandatory framework	Recommended framework
Design fire **Max HRR [kW]** **Amount of energy** **Soot, CO, CO2 yields**	- Depending of building - 20 MW - Fire Load Energy density[MJ/m²] - Pre-flash over / post flash over	- Depending of scenario - 10 MW - Heat of Combustion [MJ/kg] - Scenario based
Robustness check	Fail technical systems (sprinkler systems and automatic fire alarm not included as failing components)	Fail technical systems, non-conservative (less severe) fire
Sprinkler activation	Fire growth limited and activation criteria prescribed	Fire growth limited and activation criteria not prescribed
Deterministic performance criteria	-Visibility > 5m in rooms up to 100m² or Visibility > 10 m in rooms bigger than 100m² -$FED_{co} \leq 0.3$ (2m above floor) -$FED_{thermal} \leq 0.3$ (2m above floor)	-Visibility > 5m in rooms up to 100m² or Visibility > 10 m in rooms bigger than 100m² -CO <2000 ppm, CO_2 < 5%, -O_2 > 15% (2m above floor) -Maximal temperature of 80°C And thermal radiation of 2.5 kW/m² or short thermal radiation of 10 kW/m2 in combination with maximal energy of 60 kJ/m² added to 1kW/m² - Smoke above floor must be minimum 1.6m + (height room [m] x 0.1)
Scenarios	- Blocked exit - Fire in normally unoccupied room threatening occupants of other rooms - Fire starts in a concealed space - Smouldering fire - Horizontal fire spread - External vertical fire spread - Rapid fire spread involving internal surface linings	-Probable worst case -No detection system available: threatening occupants in other room -Robustness scenario

	- Fire fighting operations -Challenging fire -Robustness check	
Pre-movement times	Depends on familiarity, sleeping/awake and type of building	Depends on type of building and alarm type (spoken message or alarm bell)

Table 9 Comparison frameworks [6, 9]

Scenario robustness check

It is interesting to look at the Robustness scenarios of both frameworks where one component of fire safety provisions fails and an assessment is made on the impact. In New Zealand there is big confidence in the reliability of the sprinkler systems. Therefore a fail of that system should not be included in the robustness check. While in Sweden some kind of probability is introduced by defining a smaller fire when a system fails in scenario 3: robustness. The basis of this theory is that the probability of a big fire and a system failing together is very low. A smaller fire (2 MW) could be justified because of a higher probability of that event happening.

Table 10 illustrates that if the activation time for the sprinklers is below 206 seconds (in red) scenario 1 can actually be tested with a fire smaller then 2MW. This shows that it could be misleading to assume that the scenario 1 fire would be more severe than the scenario 3 fire. In Appendix 7 the input parameters and the input file for FDS can be found for a standard well-ventilated room that gives activation after 76 seconds.

	Scenario 1: Probable worst case	**Scenario 3: robustness**
Activation time [s]	**HRR [kW]**	**HRR [kW]**
60	169,2	2000
120	676,8	2000
150	1057,5	2000
180	1522,8	2000
205	1975,2	2000
210	2072,7	2000
240	2707,2	2000
270	3426,3	2000
300	4230,0	2000

Table 10 Activation sprinklers

8. Pre-movement times in Belgium

8.1. Introduction - Why is a survey necessary?

Pre-movement time is the time that people need before they react to an event. In the case of a performance based design it is the time that people need before they react to a cue related to a fire event. This cue could be from the auditory type like a fire alarm bell. Visual or olfactory cues from the fire such as smoke are also relevant in an egress situation as well.

Pre-movement time can be split up in perception - , interpretation - and action time [41]. This is also shown in Fig. 5.

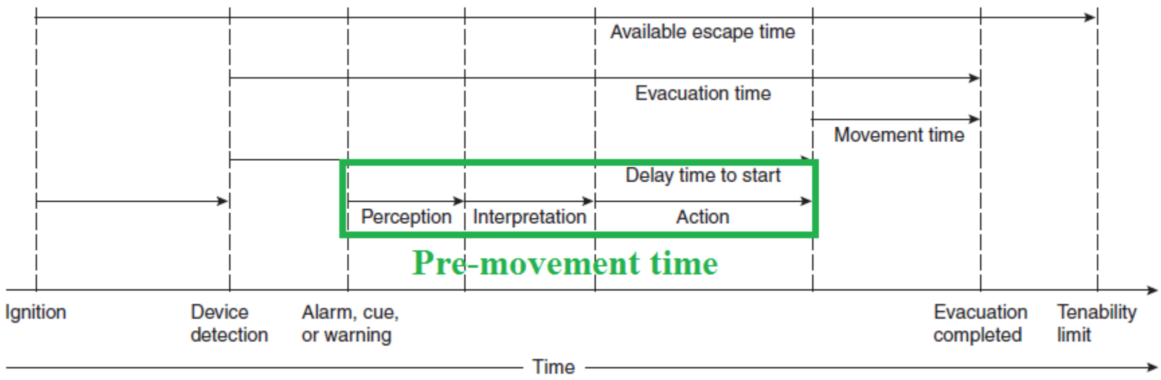


Fig. 5 Movement of People: The Evacuation Timing, SFPE Handbook of Fire Protection Engineering, 3rd ed.[41]

Depending on the type of cue the interpretation time might become shorter. For example a voice message might have a faster recognition then a classic fire bell. The action time could also dependents on social influence or the activity the people are doing (investment). It is difficult to estimate what these pre-movement times are because there is not a lot of data available. It is not easy do experiments to measure these pre-movement times because of the large amount of influencing parameters. There is in general quite some uncertainty on these values.

New Zealand has in their PBD framework C/VM2 [6] a list of pre-movement times that are relative short if compared to pre-movement times used in the United Kingdom PD 7974-6:2004 [32]. It could be interesting to investigate whether these short pre-movement times would also be applicable in Belgium. Therefore a survey could give a first idea of how the people react. It would be a first indication of their perception of risk related to a fire alarm.

8.2. The questions

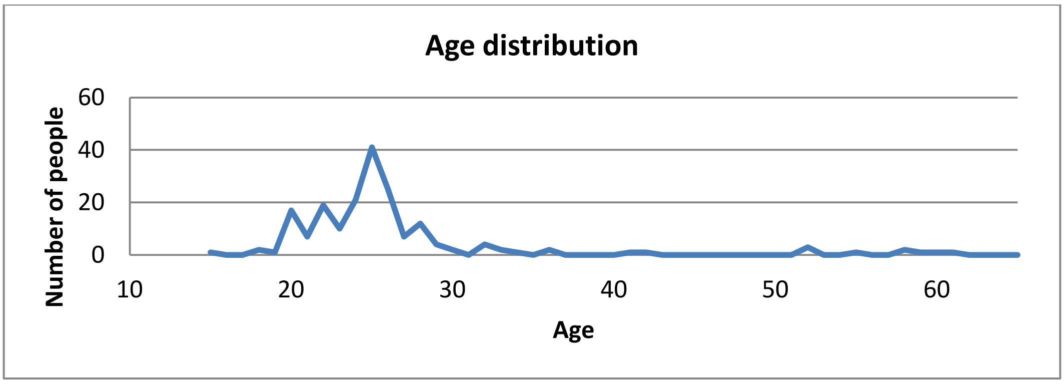
A survey is made with seven question using: '*http://www.enquetemaken.be*'. The questions can be found in Appendix 9.

8.3. Results

In total there were 194 unique participants that completed the survey. The results for all the questions can be found in Appendix 9. The results of the most important questions are given here.

- Question 2

The age distribution of the participants shows in Graph 6 a peak around the age of 25. It can be observed that 85% of the participants have an age between 20 and 30 years old.



Graph 6 Age distribution

- Question 4

The results of question 4 in Fig. 6 show that only 32% of the people actually belief that a fire alarm is the result of a fire in the building. 60% of the people agrees with the statement that it is probably only an exercise. The majority in group marked as '*Other*' answered that the alarm is the result of a technical or human error. None of the people in this group however beliefs that an alarm is the result of a fire.

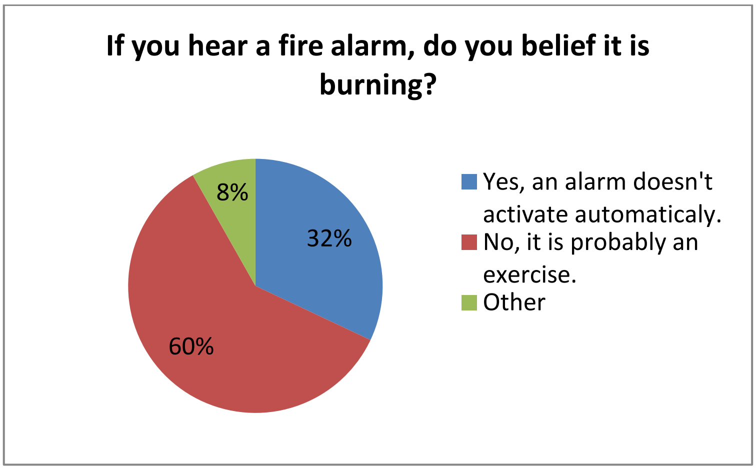


Fig. 6 Results question 4

8.4. Discussion

A group of 194 participants filled out the online survey. The distribution between men and women is quite good. If one gender would outweigh the other, different conclusions might have to be made because men might react more in fire fighting sense and women might tend to warn the others. The majority of the participants is in the age group between 20 and 30. This is largely because the social circle of the author of this research thesis. The reached age group of participants is however very relevant because it is this group of people that are going to live and use the buildings that might be developed in Belgium according to a performance based design in the future.

With the third question it was the intend of the author to make sure that the participants try to imagine a scenario that they are in. It is an attempt to create more realistic answers in the following question and not just any random, careless choice of answers. The actual answers that were filled in have quite a diversity.

The main goal of the survey is to get a sense of how people react to a fire alarm. Question 4 is the most important question to answer this objective. The results of the question shows that only 32% of the people actually belief that when a fire alarm goes off, there is an actual fire. This is a very remarkable result. It is somewhat a confirmation of what was expected but therefore not the most favoured outcome if PBD is considered. The distrust in a fire alarm is so high that a reliability of a PBD might become questionable. One of the important parameters is pre-movement time as illustrated before. The pre-movement time can be linked to risk perception [42]. If people do not link the risk of fire to a fire alarm, then there might be a fundamental problem.

The distrust in a fire alarm might be influenced by the age group. It could be possible that young people perceive a fire as less threatening, which can result in lower risk perception. More extensive research would be necessary to confirm this hypothesis.

The next set of questions are set up to get an idea about how people react and how long it would take before people react to a fire alarm. The remark has to be made that the results might not correspond with reality, but it is what the participants think what they would do if they were in the situation. For more realistic results an experiment would have to be done.

The results for the fifth question are in the line of the expectations. Most of the participants acknowledges the fact that they would look around them to see what people are doing. This social influence is a very common reaction. There is only a smaller group of about 21% that leaves the building instantly. This would be the most favoured reaction for the pre-movement times in a performance based design. Still, there is a group of 10% of the participants that would not leave the building at all if there would be no further information given. This is again not the desired result for the use of pre-movement times in a performance based design.

The next question tries to give an idea of how long people estimate that they would wait before leaving the building. The results of this question should be interpreted with great uncertainty. The results of the question only show that there is a good spread between the different pre-movement times. In the last question the expectations are again confirmed. If a second cue is presented on top of alarm signal, smoke for example, then the people perceive the risk as much more serious and leave the building instantaneously.

8.5. Conclusion

Pre-movement times can be argued to depend on local cultural habits. The main goal of the survey was to get an idea of how Belgian people react on a fire alarm. The survey reached 194 participants thus giving a fairly representative result. The age distribution pointed out that reached participants mostly where young people between the age of 20 and 30.

The results of the survey confirmed somewhat the expectation of how people would react to a fire alarm. Less than one third of the participants takes a fire alarm serious and believes it is actually burning. This makes the adoption for short pre-movement times from other publications questionable for the application in Belgium. More extensive research would be required to make hard conclusions but this first indication is not in favour of short pre-movement times in Belgium.

9. Case study

A case study is performed using the Belgian comparative approach and the New Zealand performance based design framework: C/VM2 [6] on a compartment of a high-rise building.

Fig. 7 Illustration of high-rise building

The building is a 10 storey high-rise office building, with 4 storeys below ground level. Compartment E05 I with a surface area of 1245m² on the 5th floor is studied (Fig. 8).

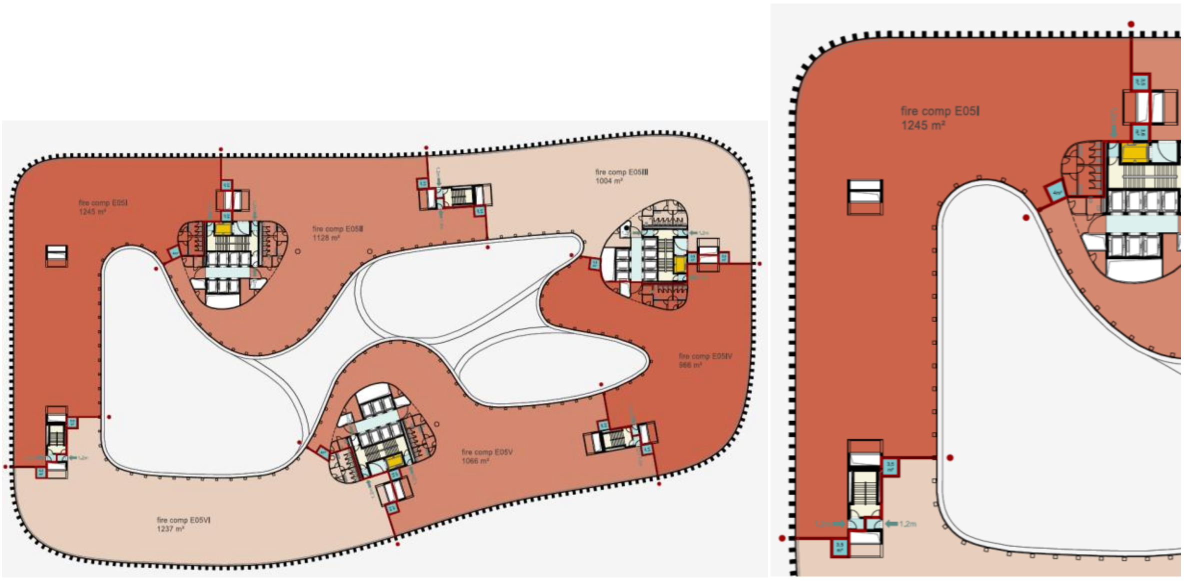


Fig. 8 Floor plan compartment

9.1. Belgian approach

The Belgian fire safety legislation is of the prescriptive type. The used version legislation is Royal Decree 12.07.2012 (B.S. 21.09.2012) + Erratum (B.S. 10.01.2014) [1] . Annex 1 and 4 of this Royal Decree need to be complied with for this case study. The most important prescriptive requirements that are of interest for this case study are listed below.

Annex 1: Terminology

1.6.2 Not public accessible: $n_p = \frac{S}{10} = \frac{1245}{10} = 124.5 = 125\ people$

5.6.5 Width evacuation routes $b_t = n_p * a = 125 * 0.01 = 1.25m$

5.6.6 and 5.6.7: minimum requirements 1.8 m width:1.2m and 0.6m
but minimum: 1.2m and 0.8m
this design: 1.2m and 1.2m

Annex 4/1: High-rise buildings

2.1.1 Compartment size: $1245m^2 < 2500m^2$

2.2.1 Number of exits: 2 exits required (<500 people)

2.2.2 Exits: placed on opposite sides of the compartment

3.2 Structural elements: R120

3.3.1 Separation between compartments in facades

3.5 Ceilings and false ceilings: on evacuation road false ceiling must have REI30. No sprinklers installed, so separations required in false ceilings REI30 with area 25m x 25m.

4.1 Walls of separating compartment: REI120
connection between compartments only with vestibule with minimum requirements: doors REI30, walls REI120 and Area $2m^2$.

4.2.2.3 Connection between evacuation route and staircase with vestibule with minimum requirements: doors REI30, walls REI120, Area $2m^2$ and width calculated in 5.6.7

4.2.2.4 Different compartments use the same staircase: separate vestibule required (4.2.2.3)

4.2.3 Staircases: R60

4.4.1 Evacuation routes: every point in a compartment must be located no further than:

- 30 m from the evacuation route leading to stairs or exits;
- 45 m from access to the nearest stairs or exit;
- 80 m from access to a second staircase or a second exit.

The red zone in Fig. 9 illustrates the points in the compartment where the distance is further than 30m to the evacuation route. This is the **first deviation.**

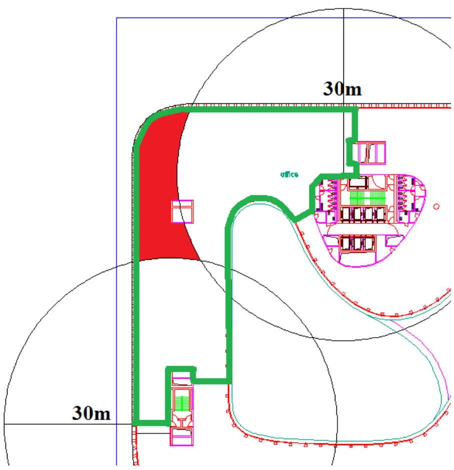


Fig. 9 Illustration 30m evacuation route

4.4.2 Connection between staircases must be guaranteed using evacuation routes. This is the **second deviation.**

Summarise deviations

There are two deviation found that have to be further investigated:

- 30m to evacuation route
- Connection between stair cases using evacuation route

9.1.1. Comparative approach

A comparative approach will be used to compare an alternative design to a design strictly following the prescriptive regulations. By demonstrating that the safety level in the alternative design is at least as high is the prescriptive design, the alternative design is likely to get approved by the Belgian authorities. The Fire Dynamics Simulator, FDS 6.1.2 [43] is going to be used as continuum fluid dynamics (CFD) software and Pathfinder 2014 [44] is going to be used as egress modelling software.

9.1.1.1. Design 1 - Prescriptive design

To be able to comply with the prescriptive legislation the design is adapted so the two deviations mentioned before can be avoided. This can be achieved by introducing an evacuation route connecting the staircases and guaranteeing a maximal travel distance of 30m to that evacuation route. The green evacuation route connects the 2 staircases in Fig. 10. The exits need to be 1.2m and 0.8m wide. The width of the escape route will also be 1.2m.

Exit width calculations:

Not public accessible: $n_p = \frac{S}{10} = \frac{1245}{10} = 124.5 = 125\, people$
Width $b_t = n_p * a = 125 * 0.01 = 1.25m$
minimum requirements 1.8 m width = 1.2m + 0.6m so minimum 1.2m and 0.8m

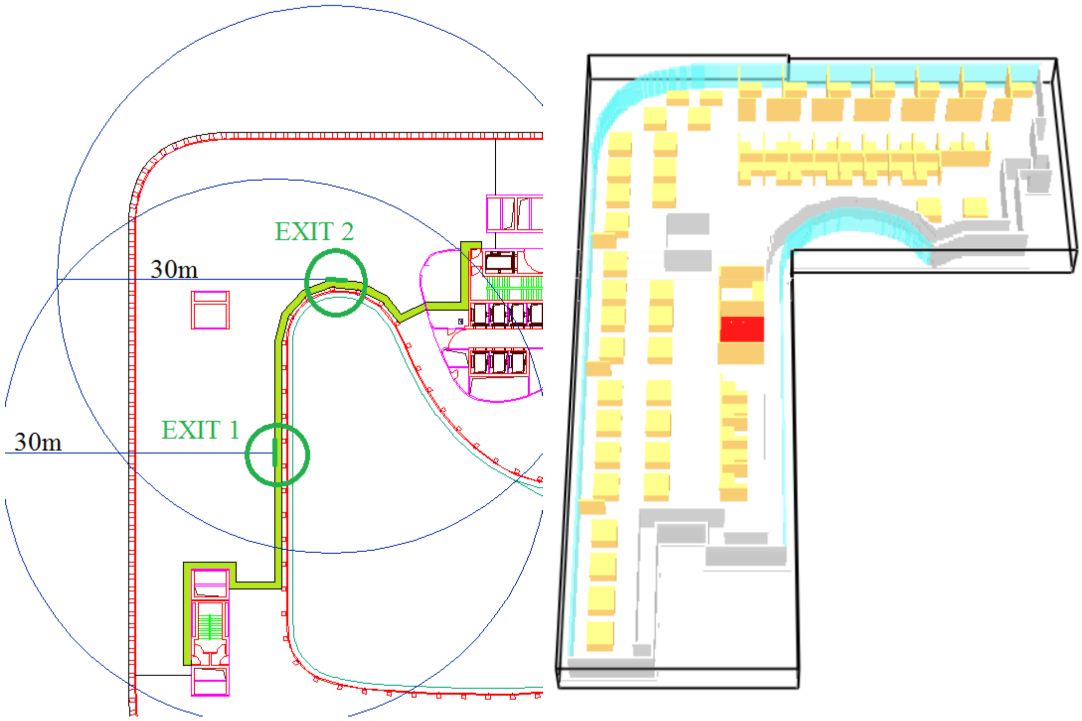


Fig. 10 Design 1 - prescriptive solution (left conceptual drawing, right geometry in Smokeview)

9.1.1.2. Design 2 - Alternative design (suggested design)

The design suggested has 2 exits on the opposite sides of the compartment, both with width 1.2m.

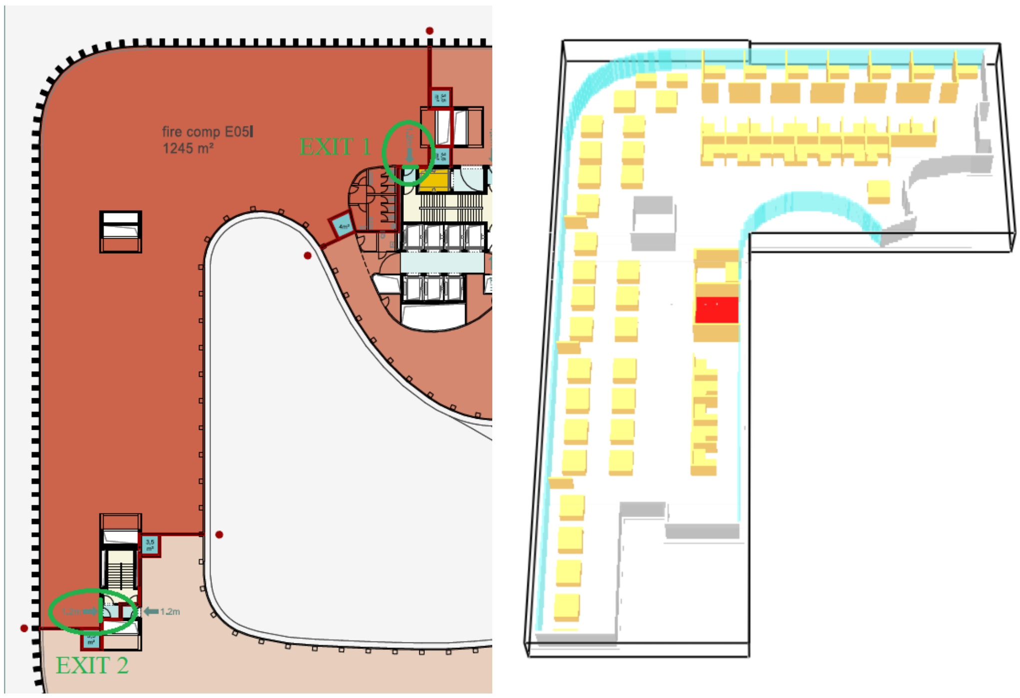


Fig. 11 Design 2 - Alternative solution (left conceptual drawing, right geometry in Smokeview)

Additional fire safety measures in the alternative design

- Size compartments: The maximal size of the compartment of 2500m² is halved to a maximal size of 1250m². The smaller the compartment the better a fire can be contained.
- Fast detection: Increase the amount of detectors. Always add a detector in separate rooms.
- Alarm voice message: With a spoken alarm message the occupants of the building are quickly aware of the situation and can react appropriately.
- Visual notification: Flashing lights at several locations in the compartment give a second cue for the occupants to divert attention to the situation.
- Training: The occupants should be well informed on what the evacuation routes are in a high-rise building. Periodic evacuation exercises can help to learn to procedures for occupants.

9.1.1.3. Scenarios

In total there will be 12 scenarios investigated for the prescriptive solution and 12 scenarios for performance based design solution. The compartment is divided up into 3 zones. In each zone the fire will be placed in a room and in the open office. Each fire will be modelled once using the 95% fractile input and once using 99% fractile input. Input parameters with a 95% and 99% fractile will be used from a technical report [45], Appendix 5.

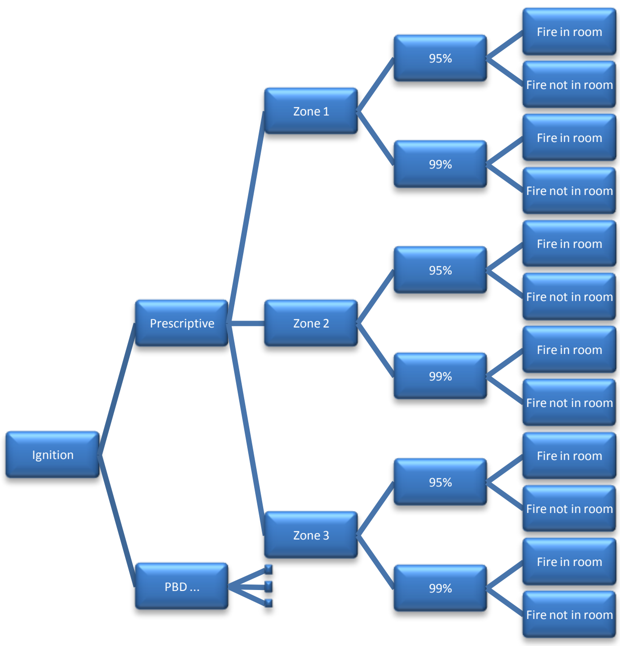


Fig. 12 Overview scenarios

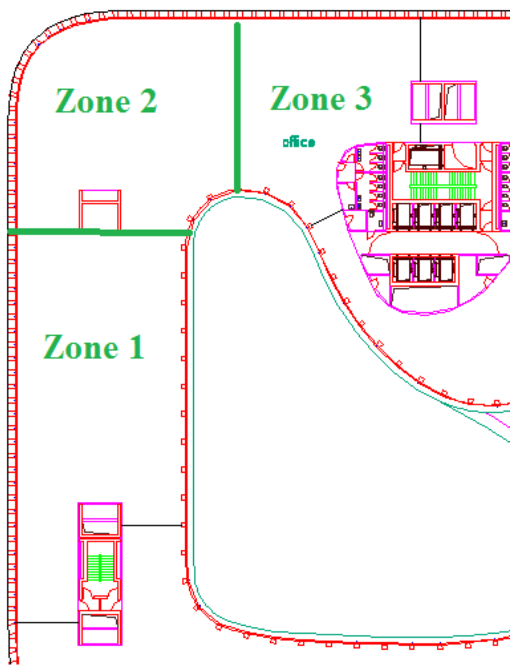
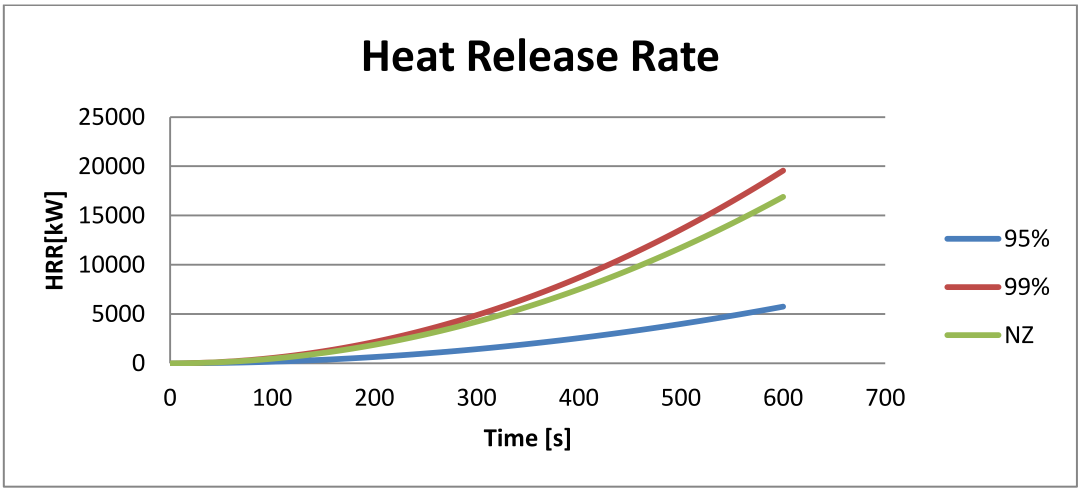


Fig. 13 Partition zones

The fire growth curves are presented in Table 11 and Graph 7 for the 95% input, the 99% input and for the New Zealand performance based design framework C/VM2. Only the growth phase in Graph 7 is presented because this is the phase focussed on for life safety considerations. Other input and the location of the fires can be found in Appendix 5.

	Fire growth coef α [kW/s²]
95% input	0.0159
99% input	0.0543
C/VM2 [6]	0.0469

Table 11 Fire growth coefficients



Graph 7 Heat release rate curves

A cubical mesh of 20cm is chosen, more information on this can be found in Appendix 5. To avoid overpressure caused by the expansion of the gasses with increasing temperature, two vents are created at location of the exits. The size of the vents are 1m x 0.2m at floor height.

9.1.1.4. Egress

Egress software - Pathfinder

The evacuation software that is used is Pathfinder 2014 [44]. An illustration of the studied compartment in Pathfinder is given in Fig. 14. This is a continuous steering model meaning every occupant has x,y-coordinates on the mesh.

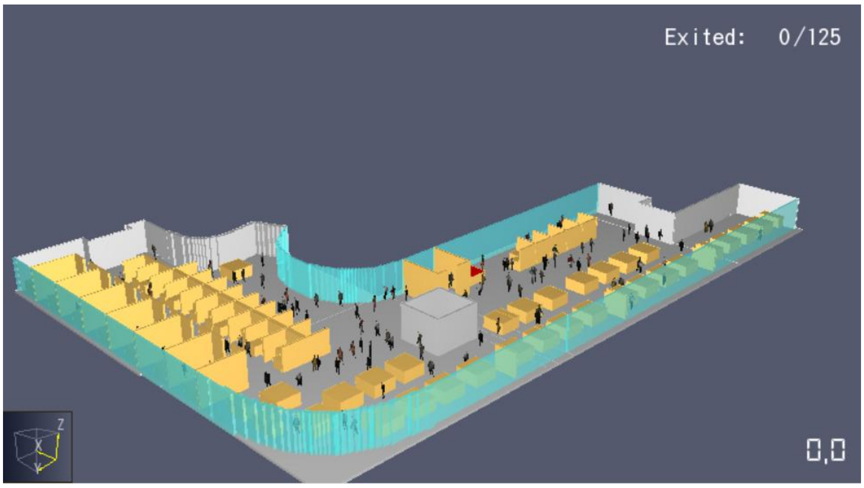


Fig. 14 Illustration of the compartment in Pathfinder

Every occupant has a 'seek goal' assigned, so he will try to reach the destination. This can be done by using 'path planning', 'path generation' and 'path following'.

- 'Path planning' is the first process where a plan is created to reach the destination. This is not the shortest route to the destination but the 'locally quickest' route. The occupants are assumed to know the room geometry and exit locations as well as where the queues are in that room. A path is planned where the occupants would be able exit the room in the quickest way based on local information.
- Once the target is determined an actual path is created in the second step, 'Path generation'. This path is the result of a combination of the A* search algorithm [46] and the triangulated navigation mesh. A mesh composed of triangles is generated with on the edges points that can be connected to create a path. Because of the sharp edges of this path it is not realistic yet, so it has to be smooth over using the 'string pulling' technique [47] resulting in the final points called 'waypoints'. It is possible that the occupant has to re-path because the straight line to the next

waypoint is interrupted. The result of connected waypoints is a 'seek curve' that defines the desired motion.

- 'Path following' can be done in Pathfinder with two techniques: SFPE mode and steering mode. In SFPE mode a flow-based egress model is used described in the *SPFE handbook of Fire Protection Engineering* [48]. Walking speeds and flow rates are suggested in the book. In steering mode Pathfinder uses steering mechanisms and collision control for the behaviour of occupants. A set of simple interaction rules can make a complex behaviour for moving occupants. The four steering behaviours defined in Pathfinder are: seek, separate, avoid walls, and avoid occupant. Using these techniques occupants can realistically deviate from their path but still be heading in the right direction.

More information on the model and the mathematical expressions for the presented techniques can be found in the Technical Reference [49].

Fig. 15 Illustration of an evacuation simulation at 20s with Pathfinder

A continuous model is attractive because it makes the simulations look realistic (Fig. 15). Furthermore this type of model is not to "user dependent", meaning the influence of the user is limited compared to network models. A drawback is that it becomes more "programmer dependent" because of the very nature of the software. Another drawback specifically related to Pathfinder is that there is no direct fire-human interaction. Output slices from a FDS simulation can be superimposed on the egress simulation but no information is exchanged.

Table 12 list the most important parameters that are used for the simulations in steering mode. In total 20 simulations are going to be performed for the design 1 geometry and the design 2 geometry. Afterwards a fairly representative average can be calculated. The occupants are placed randomly in the compartment using the random function from the software.

Input Parameter	Quantity	Source
Number of people	125 people	Belgian prescriptive legislation [1]
Walking speed (normal distribution)	Mu 1.12 m/s Std 0.25 m/s	Technical report [45]
Shoulder width	51 cm	Technical report [45]
Flow rate door	1.38 p/s	C/VM2 [6], calculated in New Zealand approach

Table 12 Input Parameters Pathfinder

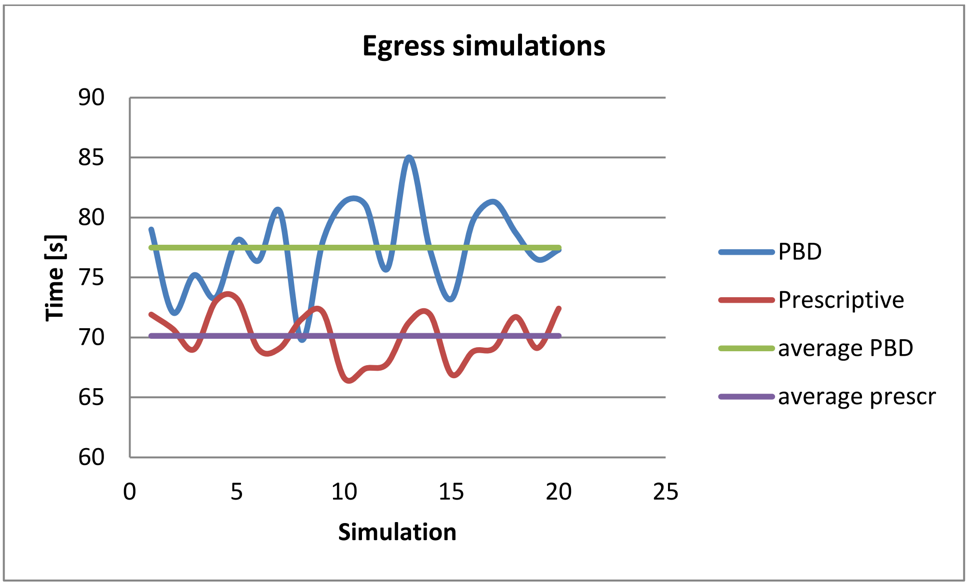
9.1.1.5. Results Pathfinder

In total 20 simulations are performed for each geometry listed in Table 13. The movement time for the prescriptive design is on average 7,4 seconds shorter than the PBD design.

Simulation	Design 1 Prescriptive [s]	Design 2: PBD [s]
1	71,9	79,0
2	70,7	72,1
3	69,0	75,2
4	73,0	73,3
5	73,2	78,1
6	69,0	76,4
7	69,1	80,5
8	71,5	69,8
9	72,1	78,0
10	66,6	81,3
11	67,4	81,0
12	67,8	75,7
13	71,2	85,0
14	71,9	77,3
15	66,9	73,2
16	68,8	79,7
17	69,1	81,3
18	71,7	78,7
19	69,1	76,5
20	72,4	77,3
Average	**70,1**	**77,5**

Table 13 Results Pathfinder egress simulations

The results are also illustrated in Graph 8 to get an idea of the spread on the results. It is clear that the movement times of the prescriptive geometry (design 1) are on average faster than the movement times of the PBD (design 2).



Graph 8 Results Pathfinder egress simulation

9.1.1.6. RSET

The required safe egress time or the total evacuation time is commonly calculated as the sum of detection time, alarm (notification) time, pre-movement time and movement time. The detection time is determined by using smoke detectors. A line of smoke detectors are placed over the fire with a distance of one meter in between starting from the centre of the fire. The six closest detectors always give a detection in less than 30 seconds. Therefore it is reasonable to assume a 30 seconds detection time. An alarm time of 10 seconds is chosen before the occupants are actually notified.

The pre-movement time is determined as the average time from the distributions in Appendix 5 coming from [45]. It is interesting to notice that the pre-movement time in Design 2 (PBD) is about 28 seconds shorter because of the different type of alarm: voice message.

The results for RSET are summarised in Table 14.

	Design 1: Prescriptive	Design 2: PBD
t_{det}	30s	30s
t_{alarm}	10s	10s
$t_{pre-movement}$	178s	150s
$t_{movement}$	71s	78s
RSET	289s	268s

Table 14 Total evacuation times

9.1.2. Evaluation of the scenarios

The available safe egress time is not directly studied but an evaluation of the scenarios is performed by looking at tenability slices at the RSET times, especially around the exits where occupants are still queuing. The last occupants are in all simulations queuing at the exit in zone 3. The performance criterion chosen to compare both designs is the Fraction Effective Dose (FED) <0.3 at 2 meters height. This is also a typical criterion in the New Zealand PBD framework. The slices on which the conclusion for the Table 15 are based can be found in Appendix 5. The evaluation to compare both designs is based on the principle that the occupants egress according to the Pathfinder model. In reality they might choose a different exit, they might not choose the exit close to the fire. Because there is no human-fire interaction in Pathfinder, this phenomenon is not included.

Location fire		Fractile	FED <0.3 (2m height)	
			Design 1: prescriptive	Design 2: PBD
Zone 1	Fire in room	95%	ok	ok
Zone 1	Fire not in room	95%	ok	ok
Zone 1	Fire in room	99%	ok	ok
Zone 1	Fire not in room	99%	ok	ok
Zone 2	Fire in room	95%	ok	ok
Zone 2	Fire not in room	95%	ok	ok
Zone 2	Fire in room	99%	ok	ok
Zone 2	Fire not in room	99%	ok	ok
Zone 3	Fire in room	95%	ok	ok
Zone 3	Fire not in room	95%	ok	ok
Zone 3	Fire in room	99%	Not ok	Not ok
Zone 3	Fire not in room	99%	Not ok	Not ok

Table 15 Evaluation scenarios

The goal of the comparative approach is to show that the suggested design is it least as safe as the prescriptive solution. From the Table 15 it is clear that design 2 is at least as safe as the proposed prescriptive solution, but is not clear yet that the suggested solution is explicitly safer.

It is illustrated with the slices in Fig. 16 and 17 that at RSET time for design 1 (RSET = 289s) and design 2 (RSET = 268s), the performance based design will always have a smaller area where FED values are reached. The same conclusion can be made about all FED-slices that were used to make the evaluation in Table 15. The conclusion can be made that the Design 2: PBD has a higher safety level then Design 1: Prescriptive solution.

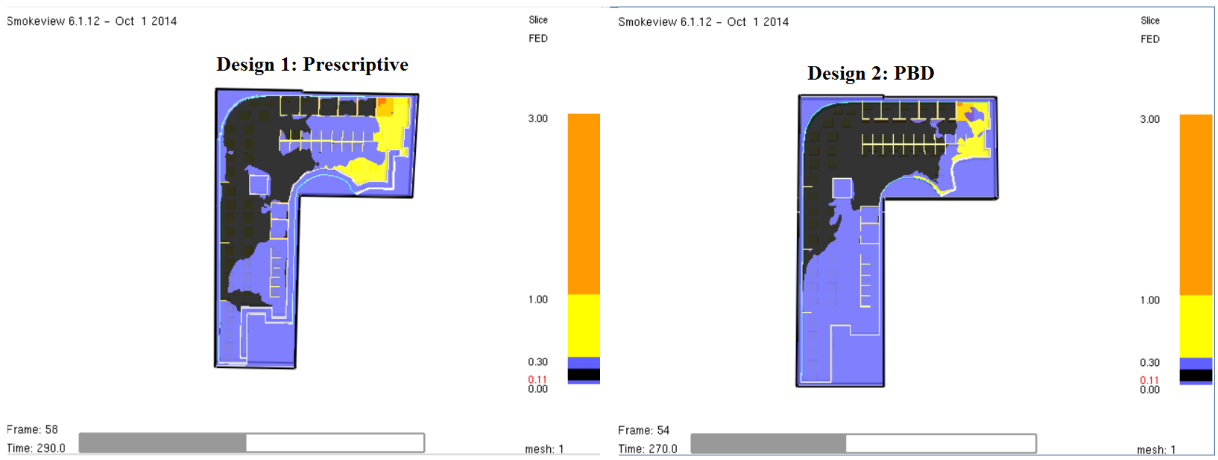


Fig. 16 Fire in zone 3, not in a room, input 95%. FED=0.11

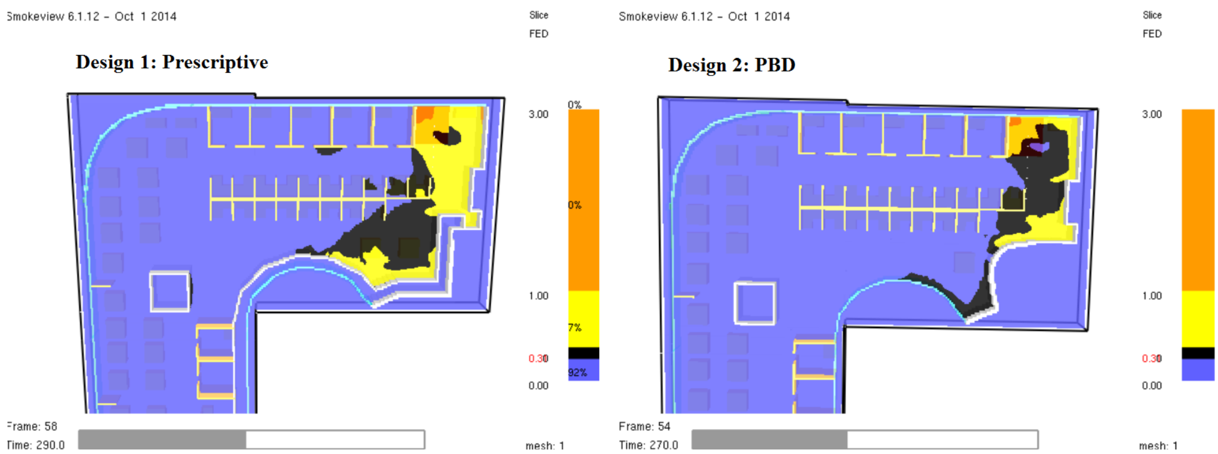


Fig. 17 Fire in zone 3, not in a room, input 99%, FED = 0.3

9.2. New Zealand approach

9.2.1 Introduction

The New Zealand approach is made according the New Zealand Building Code (NZBC) clauses C1 to C6 [18]. The main objectives related to fire can be found in C1 - OBJECTIVES OF CLAUSES C2 TO C6 (PROTECTION FROM FIRE):

> *(a) Safeguard people from an unacceptable risk of injury or illness caused by fire,*
> *(b) protect other property from damage caused by fire, and*
> *(c) facilitate firefighting and rescue operations.*

To comply with the NZBC objectives an Acceptable Solution (prescriptive type) or a Verification Method (PBD type) can be used. The performance based design framework Verification Method C/VM2 [6] will be used here.

The compartment of the building will be analysed using the 10 scenarios with prescribed fires. Each scenario can be evaluated with predetermined acceptance or performance criteria. Not all scenarios need calculations to be evaluated, some can be satisfied with provisions of specific features. Only when all scenarios are evaluated positive the design complies with the NZBC.

The stakeholders should agree upfront in the Fire Engineering Brief (FEB) process which methodology will be used. For example, the choice of fire model for the evaluation of a ASET/RSET analysis in this case the Fire Dynamics Simulator, FDS 6.1.2 [43] as continuum fluid dynamics (CFD) software. More information on the performance based design process, including FEB, can be found in Appendix 1.

9.2.2. Verification Method C/VM2

The focus of this thesis will be life safety when applying the PBD framework. However, some straightforward calculations not related to life safety are made to illustrate the use of the framework.

Occupant load

The number of occupants can be determined using table 3.1 in C/VM2. An occupant density can be found for offices of 10 m^2/person resulting in 125 people for this compartment.

Fire safety measures

Some fire safety features will be incorporated based on fire safety engineering practice in New Zealand for tall buildings.

- All structural elements are designed to resist burnout.
- At least two fire rates stairwells serve all floors .
- A building hydrant system for the fire service in accordance with NZS4510:2008 must be included in the fire rated stairwells.
- Automatic detection system and alarm installed according to a recognised national or international standard.

Scenario 1: BE - Fire blocked exit

The first scenario incorporates the possibility that a fire starts on a place that blocks an exit. The scenario has only to be investigates when there are more than 50 occupants in a compartment.

The investigated compartment has more than 50 occupants, so there are at least 2 exits required. In this case there are 2 exits, with a required distance in between of at least 8m because there are less than 250 occupants in the compartment. Therefore the design complies with this design scenario.

Scenario 2: UT - Fire in normally unoccupied room threatening occupants of other rooms

The second scenario represents the possibility of a fire that grows in a normally unoccupied room. This fire can grow significantly before it effects a room with a lot of people and consequences could be severe. Since the room has less than 150 occupants with an automatic detection system, there is no need to do an ASET/RSET analysis and the design complies with the design scenario.

Scenario 3: CS - Fire starts in a concealed space

The third scenario only applies if the investigated compartment has concealed spaces and more than 50 occupants in a room. In this compartment for example could a false ceiling be a potentially dangerous place for the unnoticed development of a fire. A solution to this problem could be to use separating elements or to include automatic detection in the concealed space. The design complies with the design scenario.

Scenario 4: SF - Smouldering fire

The fourth scenario considers a smouldering fire that could potentially endanger sleeping occupants. There are however no sleeping accommodations in the building, this scenario does not have to be considered and the design complies with the design scenario.

Scenario 5: HS - Horizontal fire spread

The fifth scenario considers fire spread to adjacent buildings. The received radiation at a relevant boundary of the property should not exceed 30 kW/m². Moreover, the radiation should not exceed 16 kW/m² at a distance 1 meter beyond the boundary (Clause C3.6 from NZBC). External walls closer than 1m to the boundary need to be constructed out of non-combustible or limited combustible materials (Clause C3.7 from NZBC). A calculation for the limiting distance to the boundary can be found in Appendix 10. The limiting distance that is found is 9 meter from the boundary. Since no information is available about the surroundings, the design complies with the design scenario.

Scenario 6:VS - External vertical fire spread

The sixth scenario considers vertical fire spread along external claddings. The height of the building is more than 10 m. But there are however no people sleeping in the building, no other property in the building and no lower roof exposure to a higher external wall within the same or adjacent building. Therefore, the design complies with the design scenario.

Scenario 7: IS - Rapid fire spread involving internal surface linings

The seventh scenario considers a rapid fire spread that could prevent occupants form escaping. The flammability of the surface linings is an crucial factor in this scenario.

The following prescriptive requirements for the buildings without sprinkler protections apply:

- Surface linings: The material group numbers are determined by fire testing ISO 9705 (full scale room corner test) or ISO 5660 (bench scale test on sample).
    - Exit ways and internal ducts: material group number 1-S
    - Other occupied spaces: material group number 3
- Flooring: The minimum critical radiant flux is determined by testing ISO 9293-1:2010.
    - Floor surface in exit way: minimum critical radiant flux is 2.2 kW/m²

    - Floor surface in other occupied spaces: minimum critical radiant flux is 1.2 kW/m²
- Flexible fabrics and membrane structures: A flammability test AS 1530-2 is required for the use of these materials.

This will not be further investigated and assumed to be fulfilled. Therefore the design complies with the design scenario.

Scenario 8: FO - Fire fighting operations

The eighth scenario considers if the fire fighters can safely operate in the building in case of fire. This design scenario has only prescriptive requirements. The performance criteria can be found in clauses C3.8, C5.3, C5.4, C5.5, C5.6, C5.7, C5.8 and C6.3 in the NZBC.

This will not be further investigated and assumed to be fulfilled. Therefore the design complies with the design scenario.

Scenario 9: CF - Challenging fire

The ninth scenario considers a worst credible scenario in a normally occupied room. An ASET/RSET analysis must be made to demonstrate that occupants can safely leave the building because the room area is bigger than 500m². The analysis is made using the same three zones and fire locations as in the comparative approach. The performance criteria can be found in Table 16. The visibility criterion will in normal circumstances be the first criterion that is reached.

Performance criteria at height 2m	
FED_{co}	≤ 0.3
$FED_{thermal}$	≤ 0.3
Visibility	> 10 m (Area >100m²)

Table 16 Performance criteria C/VM 2

RSET calculation can be made according to the framework:

$$RSET = t_{det} + t_{alarm} + t_{pre-movement} + t_{movement} \quad (9.1)$$

Where t_{det} is the time to detection [s]
t_{alarm} is the time before the alarm activates [s]
$t_{pre-movement}$ is the time from the movement people hear the alarm and actually start moving [s]
$t_{movement}$ is the time it takes of the occupants to travel out of the building [s]

The detection time is 30 s for the same reason as was discussed before. The alarm time is 30 s as prescribed in the framework. The pre-movement time is 30 s in the room of origin for buildings where people are familiar with the building and occupants are considered awake as prescribed in table 3.3 in C/VM2 [6].

The movement time $t_{movement}$ can be governed by the travel time or the flow time. Both times have to be calculated.

- Travel time

$$S = k - a\,k\,D = 1.4 - 0.266 * 1.4 * 0.1 = 1.36\;m/s \qquad (9.2)$$

Where S the horizontal travel speed [m/s]
D the occupant density of the space [person/m²]
k = 1.4 for horizontal travel [-]
a = 0.266

The travel speeds exceeds 1.2 m/s so it has to be taken as 1.2m/s.

$$\boldsymbol{t_{trav}} = \frac{L_{trav}}{S} = \frac{38}{1.2} = \mathbf{31.7\;s} \qquad (9.3)$$

Where t_{trav} the travel time [s]
L_{trav} the travel distance [m]

- Flow time

$$F_c = (1 - a\,D)k\,D\,W_e = (1 - 0.266 * 1.9) * 1.4 * 1.9 * (1.2 - 0.15) = 1.38\;\text{p/s} \qquad (9.4)$$

Where F_c the calculated flow [person/s]
D the occupant density near flow constriction[person/m²] (doors 1.9 p/m²)
W_e the effective width of component being traversed in meter [m]

$\boldsymbol{t_{flow}}$ = (125/2) / 1.38 = **45.7s**

The flow time governs, $t_{movement} = 45.7$s

ASET/RSET evaluation

First the compartment is investigated not using any active fire protection measures. The scenario would pass the ASET/RSET analysis if the visibility criterion is not reached at the exits. Table 17 shows the results of the analysis. It is clear that compartment would not pass the analysis if the fire where to be in zone 1 or 2 (marked in red). If the fire would be in zone 3 then it is assumed that all the occupants would use the exit in zone 1, resulting in a longer movement time (marked in green).

RSET		ASET	
t_{det}	30s		Visibility < 10m
t_{alarm}	30s	Zone 1, fire not in room	110s <131s
$t_{pre-movement}$	30s	Zone 1, fire in room	135s<131s
$t_{movement}$	2 exits:46s 1 exit: 91s	Zone 2, fire not in room	120s <131s
TOTAL RSET	2 exits used: 136s	Zone 2, fire in room	130s <131s
	1 exit used : 181s	Zone 3, fire not in room	220s >181s
		Zone 3, fire in room	235s >181s

Table 17 Results ASET/RSET analysis, no active protection measures

A first proposed solution is the use of smoke extraction. The extraction would be placed at the centre of the compartment, extracting smoke through the shaft. The extraction starts after 30 seconds with a flow of 10m³/s and a vent area of 1m². A sensitivity study on what the best extraction flow should be to have the best economical solution is not made. The extraction vent also creates a big under-pressure (up to 400 Pa) so more air supply should be provided mechanical or natural. Nevertheless, it would still be interesting to keep an under-pressure relative to the adjacent compartments to prevent smoke spread. A more thorough research would be required to work out this solution for a realistic design. The results of the analysis can be found in Table 18. All of the scenarios would pass the analysis. The slices to come to these conclusion can be found in Appendix 5.

RSET		ASET	
t_{det}	30s		Visibility < 10m
t_{alarm}	30s	Zone 1, fire not in room, **with extraction**	155s > 131s
$t_{pre-movement}$	30s	Zone 2, fire not in room, **with extraction**	205s>131s
$t_{movement}$	2 exits:46s 1 exit: 91s	Zone 3, fire not in room, **with extraction**	+300s>181s
TOTAL RSET	2 exits used: 136s 1 exit used : 181s		

Table 18 Results ASET/RSET analysis with smoke extraction

In a second proposed solution the compartment is investigated including sprinklers in the design. This means that only the FED_{co} criterion has to be met (clause C4.4) because of the use of sprinklers. The detection time for the sprinkler has to be modelled using FDS, resulting in a detection time of 154 s. The fire growth curve can also be adapted from the moment sprinklers activate to a steady state fire. In these simulations the fire is conservatively not reduced. The results of the analysis can be found in Table 19. All of the scenarios would pass the analysis. The slices to come to these conclusion can be found in Appendix 5.

RSET		ASET	
t_{det}	154s		FED_{co}<0.3
t_{alarm}	30s	Zone 1, fire not in room, **with sprinklers**	+400s > 260s
$t_{pre-movement}$	30s	Zone 2, fire not in room, **with sprinklers**	+400s > 260s
$t_{movement}$	46s	Zone 3, fire not in room, **with sprinklers**	+400s > 260s
TOTAL RSET	260s		

Table 19 Results ASET/RSET analysis with a sprinkler system

The two proposed solutions would both satisfy the analysis. Therefore the proposed designs complies with the design scenario.

Scenario 10: RC - Robustness check

The robustness scenario includes the failure of a key fire safety system. The scenario only has to be checked if 150 people are exposed. Only 125 occupants are considered in the analysis therefore the design complies with the design scenario.

9.3. Conclusion case study

The same compartment is investigated using the Belgian methodology and the New Zealand PBD framework. For Belgium a comparative approach is used to achieve compliance with the fire safety legislation in achieving a deviation from the prescriptive requirements. For New Zealand the C/VM2 framework is used as a stand-alone methodology.

The final design using the Belgian methodology did not include expensive active fire protection system such as a heat and smoke control (HSC) system or a sprinkler system. Only the pre-movement times where influenced by placing a voice alarm and visual recognition together with increased fire detection systems to reduce the detection time. By illustrating that the proposed PBD design is at least as safe as the prescriptive design the objective is met.

This Belgian PBD design would not be satisfactory for the New Zealand PBD framework. An ASET/RSET analysis results in a negative safety margin for most zones. This is largely because of the visibility performance criterion which is reached very fast in C/VM2. Compliance could be achieved by using a heat and smoke control system, but this was not worked out entirely as a final practical solution. Another option would be to introduce a sprinkler system. This would relax the performance criteria (only FED_{CO} criterion has to be met).

Both of the measures proposed in the New Zealand framework will be more expensive then ones proposed in the comparative approach in Belgium. But they will also increase the safety level. So if only the final result is considered, the safety level for this case study is higher for New Zealand than it is for Belgium.

9.4. Would the New Zealand performance based framework work in Belgium?

It can be a very interesting question to ask whether the New Zealand Verification Method C/VM2 would also work in Belgium. It has to be recognised that the framework developed in New Zealand is based on a local social-cultural context, e.g. influence of sprinkler systems and short pre-movement times. As was illustrated before, it were also actually these parameters that have a big influence on whether the framework would deliver a similar safety level as the New Zealand prescriptive legislation C/AS1 or the international recognised NFPA prescriptive legislation.

A question could be, is Belgian prescriptive legislation similar to the New Zealand prescriptive legislation C/AS1 or the NFPA prescriptive legislation. If it can be showed that these prescriptive rules end up in the same fire safety requirements, then it could be possible that the performance based design framework might also be applicable in Belgium.

On the other hand is it necessary that input used in a performance based design is relevant in Belgium. Some of the question might be: Is this also a typical fire that could be expected in Belgium? Can the short pre-movement times be adopted for the Belgian population? Is the effectiveness of sprinklers as high in Belgium as in New Zealand?

It becomes clear that adoption of the New Zealand PBD framework would only be possible if choices of quantified input and methodology are valid in Belgium as well. These choices can be linked to a social-cultural context: short pre-movement times, confidence in sprinkler systems, etc. It would not be surprising that there are cultural differences between countries on opposite sides of the world. One of the investigated aspects are the pre-movement times in Belgium. It seems that the adoption of short pre-movement times would not be realistic in the Belgian social-cultural context according to the survey.

Furthermore, it is typical in the development of a PBD framework to compare the outcome with the outcome of a prescriptive legislation. For this case study, the New Zealand PBD framework would be more conservative than Belgian prescriptive legislation because of the need for more active fire protection systems. This insinuates that a higher level of safety is demanded in New Zealand. If this was the sole goal, to achieve a higher level of safety, then ultimately the framework might be useful in Belgium after all.

Still, a lot can be learned from New Zealand on how the methodology of the framework is build up and which inputs are chosen to be quantified, although the magnitude of the numbers might not be exactly representative for Belgium. It is suggested in previous chapters that many of the input parameters are related to each other, creating a final safety level. This was illustrated in the form of a ratio for the design fire input and performance criteria. This principle could be used in the development of a Belgian framework. The New Zealand framework might not be the exact framework we need, but it might give a baseline how to develop a deterministic framework in Belgium.

10. Discussion

A safe design can be made using two different routes. A performance based design (PBD) could be made or a design according to the prescriptive regulations. The safety level achieved should ultimately be the same, regardless of which method that was used. For the acceptance of a performance based design framework, the reference on which level of safety that should be achieved is based on the prescriptive design. This can be found in the evolution of the PBD framework of New Zealand to the current framework C/VM2 [6]. But is this a good way of evaluating a PBD framework?

To be able to fully understand the differences between prescriptive design and PBD in a regulatory system the influencing factors must be investigated. Fig. 18 shows in a diagram the influencing parameters of a safe design. A safe design can be made by using a performance based design framework or following a prescriptive design.

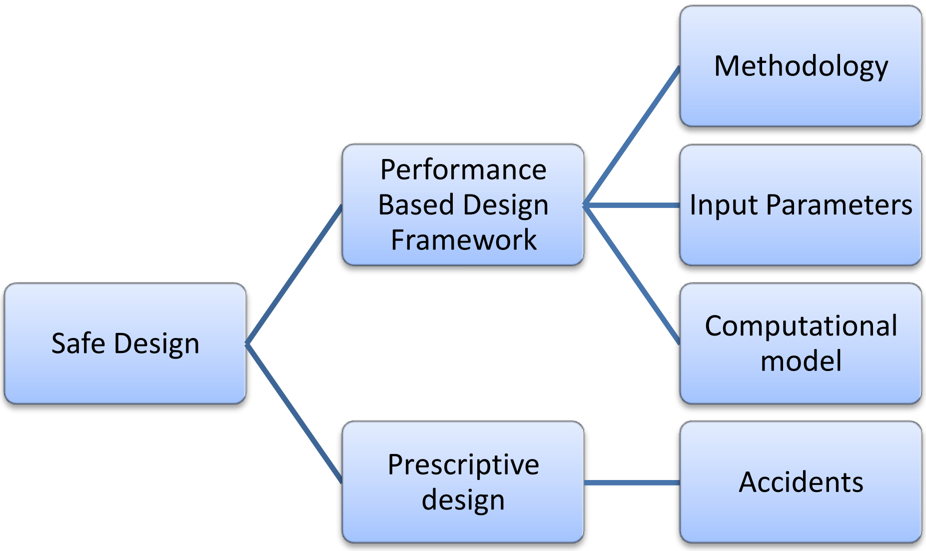


Fig. 18 Diagram Safe Design

An argument for making the prescriptive design the reference for the required safety level is that it is the reflection of what a society accepts in terms of safety. This statement could be criticised. The perception of risk on fire safety is related to accidents that have happened in the past. It is only after a dramatic event that regulations are changed [50]. So there is always a time related lag on the regulations adaptations while buildings and societies continue to develop. Moreover, because of the low frequency character of severe fires it is possible that certain aspects might never be taken in consideration in a design whatsoever if coincidentally no accidents happen. Only after an drastic event, awareness is raised for a problem and a reaction is provided in terms of a change in regulations, so this accident must never happen again.

Keeping this in mind, should the prescriptive design still be the reference for the required safety level? Could it be possible that more accidents would be avoided if a performance based design actually becomes the reference for safety and the prescriptive regulations are adapted? This time lag of adaptation in the prescriptive regulations might be caught up by designing in a flexible framework where innovation and future perspectives are key aspects. This methodology of course requires a robust and reliable performance based design framework.

According to the author of this research thesis the first big influence on achieved safety level of a PBD framework is the methodology that is used. Depending on the framework some parameters or steps are prescribed, for others it is up to designer to make good choices. Some design scenarios for example do not have to be checked because of low occupant density or limited surface area. As showed in the re-evaluation of some of the case studies in the research thesis [2] some scenarios are excluded from the design because of the prescribed methodology.

One of the major parts in a methodology is the way fire events are considered, because they form the basis of an analysis [30]. Here a good definition is given: *"A design fire is a product of all the relevant and influencing variables of the problem".* It is stated that a fire event most important properties are fuel properties and environmental factors. These can be defined as [30]:

- ***Fuel properties****: composition of the fuel (heat of combustion, heat capacity, thermal conductivity and density) and the presence of retardants.*
- ***Environmental factors****: fuel load, composition of atmosphere, pressure, temperature, imposed heat flux, air velocity, surface orientation, confinement geometry, material properties, direction of flame propagation, fuel continuity, and infrastructure-imposed constraints.*

There should be some methodology prescribed to guide the engineer in creating a design fire. But only having the option for a prescribed fire would be a bad evolution because of the increase in complexity in modern buildings that require an unique detailed analysis. The real problem lies in the translation tool [30]: now there is no tool available where the fuel properties and environmental factors are considered to create a design fire. Current tools such as CFD software only give the translation of input (HRR, yields, etc.) chosen by the engineer or framework translated to output (temperatures, smoke production, etc.).

A second big influence is the quantitative choice of the input parameters. Where previously these input parameters where only described qualitative, now an explicit number is suggested or imposed. The choices of this numbers strongly effect how conservative the outcome is. There is a variety of numbers available in the literature but no uniform acceptance. Here the use of a ratio is suggested to define a safety level combining different input parameters.

A third influence on the result is the choice of a computational model. To model the fire a CFD modelling software could be suggested by a PBD framework. But designing a good representative model requires a lot of information and detail. Apart from the necessary input, different calculation methods result in a different outcomes. A research thesis [51] showed that FED and FEC levels in FDS5 are 10% overestimated compared to FDS6 based on results of previous studies. If 10% would be the reasonable safety margin chosen in the PBD, then the choice of software would already have counteracted this safety margin. If a simple zone model was chosen, this might even result in different conclusions. So the choice of the calculation model also influences the final conclusion.

To conclude, there are three main groups of sources that influence the final outcome of a performance based design. It is only when they are all well balanced and based on realistic choices, that a PBD framework will give good results. When the choice is left up to the designer, it is still his moral duty to make acceptable choices. The question remains whether a PBD framework instead of a prescriptive design could be a good basis for determining the safety level that should be achieved in buildings. Maybe in a further stage of the fire safety engineering science, with a well recognised PBD methodology, recognised distributions of input parameters and reliable computational models, a PBD framework would be the better reference for the achieved safety level. But in the opinion of the author a PBD framework has on this moment not yet reached that level of reliability.

11. The future of PBD in Belgium

Using performance based design methodologies has many advantages. An important element of PBD is freedom in design, flexibility, etc. But this works two ways, where this is a huge advantage for the designer, this introduces a consistency problem for authorities in achieved levels of safety. Countries like New Zealand created some sort of prescribed performance based framework to handle this. It is an interesting tool for designers and a good solution for authorities. It is a compromise between PBD and prescriptive legislation. But is this a good evolution, is PBD not moving further away of its essence if it becomes more prescriptive?

A different solution to the problem of inconsistency might be to recognise the title Fire Safety Engineer and protect it for engineers that have demonstrated that they have the required skills, knowledge and understanding of the sector requirements. Now it could become the responsibility of the engineer to design safely in a much more explicit manner: the engineer could lose his protected title in case of insufficient performance. In this type of system, more freedom could be given to the designer because his decisions make him directly liable. This could result in the engineer making choices with less risk and ultimately safe designs. The question again becomes how much freedom should be given to the designers. Putting this type of system in place would however be a practical challenge but could be further investigated.

12. Conclusion

A design that guarantees fire safety in a building can be achieved in two different ways. A prescriptive legislation such as the Belgian legislation can be used to design a building. A set of prescribed rules make it possible to design a standard building. Or a performance based design (PBD) could be made because of the many advantages. One obvious advantage is the flexibility in building designs such as big open spaces, atria, etc. Currently, there is no legally recognised framework in Belgium to make a PBD. However, there is the possibility to deviate from the prescriptive legislation using for example a comparative approach, illustrating that the alternative suggested design is at least as safe as the prescriptive design. But there are no formal guidelines for this procedure.

Other countries such as New Zealand and Sweden already have the possibility to make a PBD design in their legislation. In this research thesis the focus was put on New Zealand because of the well documented process of the development of their PBD framework. When PBD was first allowed a variety of different safety levels where found in designs. This inconsistency problem for the authority having jurisdiction created the need for a robust framework. It was discussed which input parameters could be prescribed in a PBD framework. A ratio was suggested to make the relation more explicit between the input parameters.

It was found that the first developed PBD framework in New Zealand was too conservative and had therefore to be relaxed to get a similar level of safety as what would be achieved with the prescriptive legislation. The remarkable changes in the new framework are: shorter pre-movement times, not applicable scenarios, ASET in room of fire origin, performance criteria and fire size. The new framework was then tested again in this thesis for the same case studies from the former research thesis where the first conceptual framework failed. The influences of these changes were recognised because almost all scenarios passed and therefore achieved the same level of safety as the prescriptive legislation.

The choice for shorter pre-movement times in the PBD framework was further investigated. A survey was conducted with a response of 194 people to get an idea if these short pre-movement times would be realistic for the Belgian population. Only 32% of the people thought it was actually burning when they were asked what they think if they would hear a fire alarm. Based on that result, the conclusion would not be in favour of these short times.

A case study was performed on a compartment of a high-rise building using the Belgian comparative methodology and the New Zealand PBD framework. Two designs were made for the comparative approach: a design according to the prescriptive legislation and an alternative design that deviates from the legislation. It was found that the measures that needed to be taken to achieve the required safety level in Belgium where minor: reduced pre-movement time, by introducing a voice alarm and visual notification together with fast detection by increasing detection points. To achieve compliance with the New Zealand PBD framework a heat and smoke control system or a sprinkler system would be required. Ultimately would the design according to the New Zealand framework have a higher safety level.

A discussion was presented on the influencing factors on prescriptive design and performance based design. For the prescriptive design the biggest influence that could result in a change of regulations would be severe accidents. For performance based design the main influences on achieved safety level would be the used methodology, input parameters and computational model. It was concluded that having the prescriptive legislation as the basis of the required safety level would still be the right choice for now. Maybe in a further stage of the fire safety engineering science, with a well recognised PBD methodology, recognised distributions of input parameters and reliable computational models, a PBD framework would be the better reference for the required safety level.

The question whether the New Zealand PBD framework would work in Belgium was discussed. The methodology and input parameters seem to be related to a social-cultural context that might not entirely be applicable in Belgium. However, the framework could be a good baseline to create a deterministic framework for Belgium if that is the goal. It was also discussed that these types of prescriptive PBD frameworks might not be ultimately going in the right direction for the good of performance based designing where flexibility is one of the great advantages. Giving back designing freedom to the engineer by protecting the title Fire Safety Engineer might also be a solution that could be further investigated.

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Appendix 1: Countries with Performance Based Design

There are already quite a few countries that have adopted the option to use a performance based design to meet the fire requirements. Most facts presented below are gathered from *Performance-Based Building Regulatory Systems - Principles and Experiences* [52]. An overview of these countries is given here.

Australia

The Building Code of Australia (BCA) is a performance based code issued by the Australian Building Code Board (ABCB). It is active since 1997. There is possibility to meet de performance requirements using a deemed-to-satisfy solutions (prescriptive).

Website: http://www.abcb.gov.au

Austria

The Austrian Institute for Construction Engineering (OIB) has developed the OIB-guidelines. These guidelines are a first-generation mix of prescriptive and performance based methods. The final goal is the have a full performance based regulation [52].

Website: http://www.oib.or.at/

Canada

Canada transformed their prescriptive National Building Code of Canada in 2005 to an objective based type. Each prescriptive rule was linked to clear objective creating an acceptable solution. An alternative solution was also created as objective based method allowing performance based design.

Website: http://www.nrc-cnrc.gc.ca/eng/index.html

China

The Residential Building Code introduced in 2005 is mostly of the performance based type, but still has quite some prescriptive requirements. The evolution is ongoing towards a more performance based standard, but the existence of prescriptive regulations is ensured. The China academy of Building Research (CABR) is a research facility developing these codes and standards.

Website: http://www.cabr.com.cn/engweb/index.htm

Japan

The Building Standard Law (BSL) and Regulations include since 2000 Performance Based Codes (PBC). The new PBC was made to coexist with the current regulations. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is in charge of the BSL and Regulations. Because of frequency and severity in seismic activity and typhoons MLIT has a vital responsibility. The National Institute for Land and Infrastructure Management (NILIM) provides the MLIT of technical support.

Website: http://www.mlit.go.jp/en/index.html

England

Awareness for the dangers of fires can be traced back to 1666, The Great Fire of London. England and Wales were one of the first to introduce a performance based design regulation in 1991. The functional approach is a document of only nine pages but backed up by Approved Documents (ADs) that give guidance on how to comply with the regulations. Designing an alternative solution is also possible if the solution is at least as 'good' as the one in the ADs.

Website: https://www.gov.uk/

Netherlands

The Building Decree came into force in 1992 to create uniform technical specifications. The regulation is of the performance based type. The performance requirements are expressed by a functional description for each clause. A prescriptive acceptable solution is always given but performance requirements are more qualitative then quantitative [50].

Website: http://www.bouwbesluitonline.nl/ (Dutch)

New Zealand

New Zealand was also one of the first to develop a performance based regulatory system. The developments of this country will be discussed extensively in the next chapters.

Website: http://www.dbh.govt.nz/compliance-documents

Norway

The National Office of Building Technology and Administration (NOBTA) is responsible for development and guidance of the building regulations. Performance based regulations were introduced in 1997. They did not replace the prescriptive regulations, but coexisted. In reality is performance based engineering in Norway in many cases a mix of pre-accepted solutions and deviations [53].

Website: http://www.dibk.no/ (Norwegian)

Singapore

Building and Construction Authority (BCA) is since 1999 in Singapore the administration that regulates the building control system. In 2004 a performance based approach was introduced and still coexists with the old prescriptive requirements as acceptable solution to the performance requirements.

Website: http://www.bca.gov.sg/

Spain

In 2006 the Technical Building Code (Código Técnico de la Edificación or CTE) was approved. The old prescriptive regulations were translated in a performance based approach. But there are also 'official methods of fulfilment' to achieve compliance with the performance requirements in a prescriptive way.

Website: http://www.codigotecnico.org/ingles/introduction/

Sweden

In 1994 the regulations changed from prescriptive to function based design in Sweden. The developments of this country will be discussed extensively in the next chapters.

Website: http://www.boverket.se/en/start-in-english/publications/2012/building-regulations-bbr/

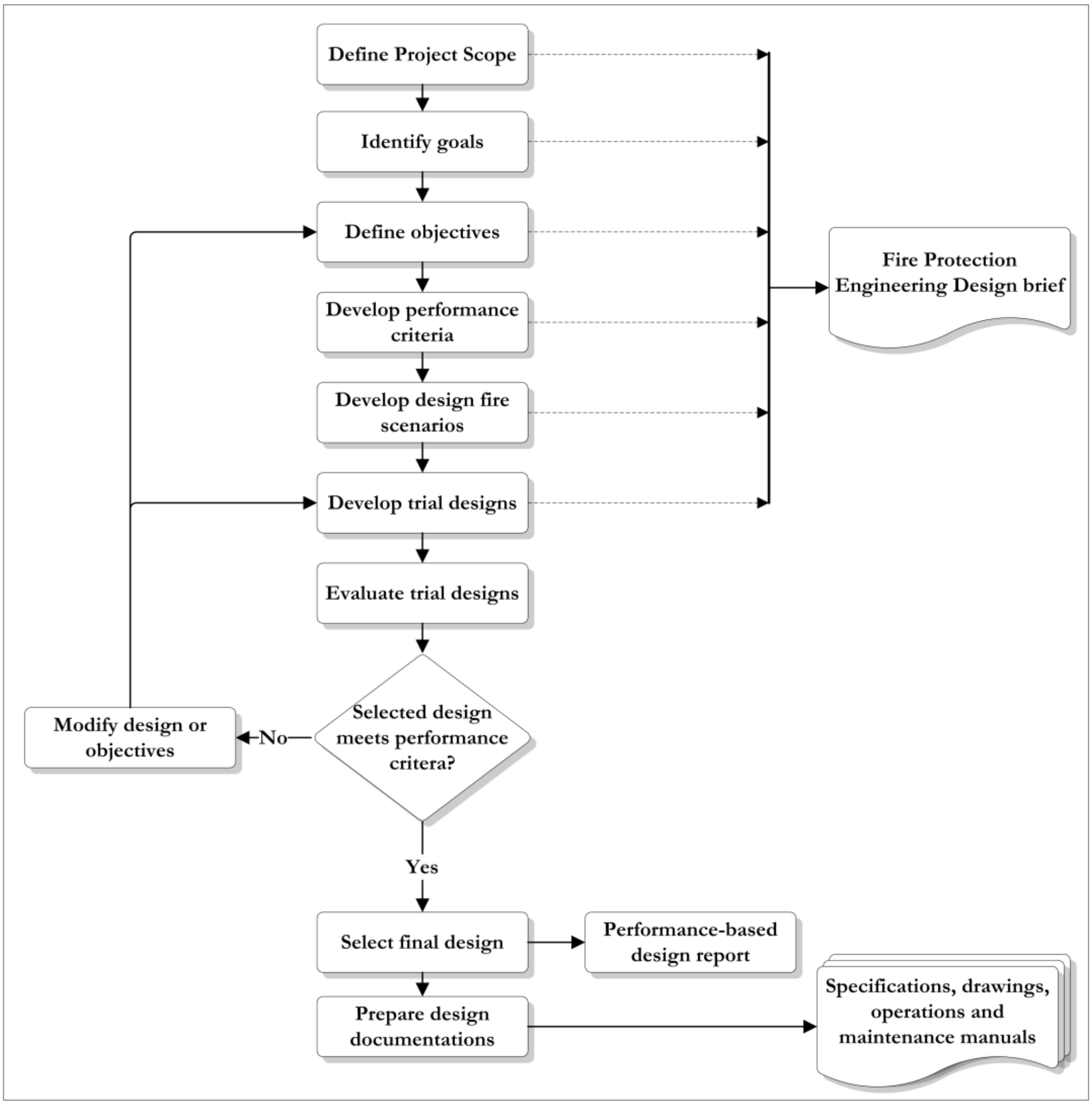
United states

The overall regulatory system of the United States of America (USA) is going towards a more performance based system. There are a number of documents that confirm this (e.g. SFPE Engineering Guide to Performance-Based Fire Protection [4]. The International Code Council (ICC) develops codes that are adopted by the states of the USA in their legal system (i.a. 2009 ICC Performance Code for Buildings and Facilities - ISBN: 978-1-58001-738-1 [54]. NFPA codes are also extensively used.

Website: http://www.iccsafe.org/

Appendix 2: What is performance based design?

Performance based design is a methodology to achieve compliance with fire safety regulations for buildings. It is engineering approach that allows calculations and engineering insights to prove that the fire safety requirements are fulfilled. The figure below gives a flowchart of how the process works suggested by SFPE Engineering Guide to Performance-Based Fire Protection (The Guide) [4].



Performance based design flowchart from SFPE Engineering Guide to Performance-Based Fire Protection [3]

The different steps presented in figure above are further explained here.

Design Brief

The design brief is a document that gives an overview of the following steps in the performance based design: Define project scope, Identify goals, Define stakeholder and design objectives, Developing performance criteria, Developing design fire scenarios and Developing trail designs. The purpose is to have every step well documented. This is crucial for a performance based design.

Define project scope

The first step in the PBD process is to define the scope of the project. It is important to define the boundaries of the project so analysis can be made. It should be known for what type of building that fire safety requirement have to be designed, the use of building, the applicable building regulations, the available budget, etc. A very important part of the scope is de identification of the stakeholders: Building owner, manager, design team, authorities have jurisdiction, construction team, accreditation agencies, tenants, building operation and maintenance, emergency responders and peer reviewer.

Identifying goals

There are two possible sources for the goals: stakeholders and the applicable building regulations. The Guide defines four fundamental goals for fire safety:

- ***Life Safety****: Provide life safety for the public, building occupants, and emergency responders by minimising fire-related injuries and preventing undue loss of life.*
- ***Property protection****: Minimize damage to property and cultural recourses from fire (e.g. protect building, contents, and historical features from fire and exposure to and from adjacent buildings).*
- ***Continuity of operations****: Provide for continuity of operations (i.e. protect the organisation's ongoing mission, production, or operating capability). Minimize undue loss of operations and business-related revenue caused by fire related damage.*
- ***Environmental protection****: Limit the environmental impact of fire from combustion products and release of hazardous materials.*

Define stakeholders objectives and design objectives

If the fire safety goals are agreed upon by the stakeholders then the next step is to translate the goals to objectives. The objectives are technical definitions for the specific project. The objectives are defined in acceptable terms of loss or level of risk.

Developing performance criteria

After defining the objectives the next step is to develop the performance criteria to be able to evaluate whether a design meets the objectives. These performance criteria are values that have to be decided upon by the engineer or prescribed in a performance based regulatory framework. Typical life safety parameters are temperature, radiation levels, smoke concentration or visibility, toxicity levels of carbon monoxide (CO) or carbon dioxide (CO_2). Typical non-life safety criteria are thermal effects on structure, fire spread, smoke damage, fire barrier and structural integrity, damage to exposed property and damage to environment. These criteria should be determined before the analysis and not be relaxed after unsuccessful design.

Developing design fire scenarios

Now the design fire scenarios can be developed. These scenarios should cover a wide range of possible fire events placing fires on different places, blocking egress, smouldering fires etc. There are in the literature some suggestions on how to chose different scenarios deterministically or using a probabilistic approach. The design fires and occupant characteristics should also be developed for each scenario using the available literature or prescribed in a performance based regulatory framework.

Developing trial designs

The last part that has to be developed is the trial designs. Each trial design is a combination of fire safety measurements to achieve fire safety. A trail design can consist of active fire safety systems such as sprinklers, where another trail design can only consist of passive systems such as self closing fire rated doors. The trail designs are made to test if the performance criteria are satisfied.

Evaluating trail designs and selecting final design

The next step is to check whether the trail design meets the performance criteria if it is applied on the design fire scenario. This is done by using recognized fire safety engineering calculations or computer modelling in a deterministic analysis. Another possibility is to do a probabilistic analysis such as a quantified risk analysis (QRA).

After the analysis it should be clear which trail designs meet the requirement and can be selected as final design. If all of the trail designs fail then the design or the objectives should be modified and evaluation should be repeated.

Documentation and specifications

Finally a report should be made including all the used information. Documentation is very important to justify the performance based design. Not only to validate the choices made in the design but it could be important for the maintenance of the building or future adaptation of the building. Therefore also an operation and maintenance manual should be developed for full understanding of the building for people other than the designer.

Appendix 4: Evolution design scenarios

Scenario	Type	Description
1	Conceptual framework 2008	Challenging fire: **credible worst case**
	Conceptual framework 2011	These fires are intended to represent a **credible worst case** scenario that will challenge the fire protection features of the building.
	NFPA	Occupant specific fire representative of a **typical fire** for the occupancy.
2	Conceptual framework 2008	Blocked **egress**: an escape route is blocked
	Conceptual framework 2011	Fire is located near the primary **escape route** or exit that prevents occupants form leaving the building by that route. Fire Originating within an exit way may be the result of a deliberately lit fire.
	NFPA	An ultra-fast developing fire in the **primary means of egress**, with interior doors open at the start of the fire
3	Conceptual framework 2008	**unoccupied** space: fire grows unnoticed in room and effects nearby big number of people
	Conceptual framework 2011	A fire starting in an **unoccupied space** may grow to a significant size undetected and spread to other areas with the greatest number of occupants.
	NFPA	A fire that starts in a normally **unoccupied room** potentially endangering a large number of occupants in a large room or other areas
4	Conceptual framework 2008	**concealed** spaces: fire grows unnoticed in void or duct and effects nearby big number of people
	Conceptual framework 2011	A fire that starts in a **concealed space** could develop undetected and spread to endanger a large number of occupants in a room.
	NFPA	A fire that originates in a **concealed wall or ceiling** space adjacent to a large occupied room.
5	Conceptual framework 2008	Sleeping occupants: **smouldering** fire in sleeping areas
	Conceptual framework 2011	**Smouldering** fire that causes a threat to sleeping occupants
	NFPA	A **slowly developing** fire, shielded fire protection systems, in close proximity to a high occupancy area.
6	Conceptual framework 2008	Horizontal fire spread: to **other buildings**
	Conceptual framework 2011	A large fire within a building may spread to **neighbouring buildings** as a result of heat transfer.
	NFPA	Most severe fire resulting from the largest possible fuel load characteristics of the normal operation of the building
7	Conceptual framework 2008	**vertical** fire spread: from lower to upper levels
	Conceptual framework 2011	A fire source adjacent to an external wall such as a fire plume emerging from a window, or a fire source in close to facade that could ignite and spread **vertically**.
	NFPA	External exposure fire
8	Conceptual	**Surface linings**: untenable conditions in escape routes

	framework 2008	
	Conceptual framework 2011	A flaming fire source located in a wall-corner junction that potentially ignite room **surface lining** materials and subsequently leads to untenable conditions on a escape route.
	NFPA	Fire originating in ordinary combustibles in a room or area with each passive and active protection system independently **rendered ineffective**.
9	Conceptual framework 2008	N/A
	Conceptual framework 2011	Provide **fire fighters** with the means to fight the fire with an element of safety
	NFPA	**Additional scenarios**: - high-frequency, low consequence scenarios - low-frequency , high consequence scenarios - special problems scenarios
10	Conceptual framework 2008	N/A
	Conceptual framework 2011	Test the **robustness** of the design by considering the design fire with each key fire safety system **rendered ineffective**
	NFPA	N/A

Design Fire Scenarios

Appendix 5: Simulations

Mesh size

If the ratio $\frac{D^*}{\delta x}$ gives a number between 4 and 16, it would be acceptable according to the FDS user guide. δx is a dimension of the mesh and D* can be calculated as followed:

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

with $\dot{Q}$ = 2065; 7042; 6078.24 kW
ρ_∞=1.2 kg/m³
C_p=1 kJ/(kg K)
T_∞=293 K
g=9.81 m/s²

For a **20cm** grid the following calculation can be made:

	BELGIUM 95%	**BELGIUM 99%**	**NEW ZEALAND**	
HRR(360 s)	2065	7042	6078,24	[kW]
D*	1.3	2.1	2.0	[-]
$\frac{D^*}{\delta x}$	6.4	10.5	9.9	[-]

The calculated number show that a 20cm grid is a good choice.

Input Belgian comparative approach

Input parameters with a 95% and 99% percentile will be used from a technical report[45].

nr	Type	Distr type	Par 1	Value	Par 2	value	Unit
1	Fire growth coef α	Lognormal	Mean μ	-7.1	Stand σ	1.8	[kW/s²)
2	HRRPUA	Normal	Mean μ	311.8	Stand σ	66	[KW/m²]
3	Area	Lognormal	Mean μ	0.83	Stand σ	2.14	[m²)
4	Occupant density	Gumbel (max)	μ	83.2	α	0.0854	[p]
5	Detection sensitivity	Lognormal	Mean μ	-2.41	Stand σ	0.85	[OD/m]
6	Pre-movement time: general	Lognormal	Mean μ	5.18	Stand σ	0.17	[s]
	Pre-movement time: Voice Message	Normal	μ	150	Stand σ	10	[s]
7	Walking speed	Normal	Mean μ	1.12	Stand σ	0.25	[m/s]
8	Heat of combustion	Normal	Mean μ	25	Stand σ	4	[kJ/g]
9	Prod of comb: soot	Normal	Mean μ	0.12	Stand σ	0.04	[g/g]
10	Prod of comb: CO	Normal	Mean μ	0.09	Stand σ	0.03	[g/g]
11	Prod of comb: HCN	Normal	Mean μ	0.006	Stand σ	0.002	[g/g]
12	Susceptibility	Beta	α	7.5186	β	4.1422	[%COHb]
13	Affiliation: no training	Normal	Mean μ	60	Stand σ	15	[-]
	Affiliation: with training	Normal	Mean μ	30	Stand σ	15	[-]
14	Shoulder width	Normal	Mean μ	0.51	Stand σ	0.07	[m]
15	VE rate person	Normal	Mean μ	25	Stand σ	5	[m]

Input parameter	**95%**	**99%**
Ysoot [g/g]	0.19	0.21
Y_{CO} [g/g]	0.14	0.16
Y_{HCN} [g/g]	0.0093	0.0107
Heat of Combustion [kJ/g]	18.42	15.69
HRRPUA [kW/m²]	420.36	465.36
Fire growth coef α [kW/s²]	0.0159	0.0543

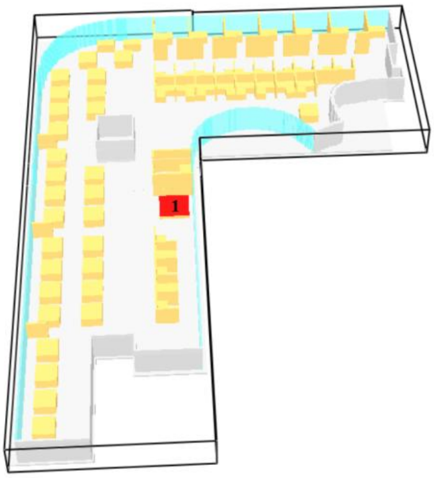
Characteristics materials

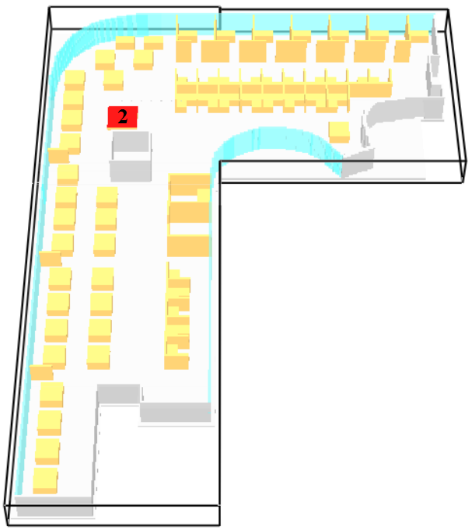
	Concrete	**Glass**
Thickness [cm]	14.0	5.0
Specific heat [kJ/kgK]	1.0	0.8
Density [kg/m³]	2300.0	2500.0
Conductivity [W/mK]	1.6	0.8

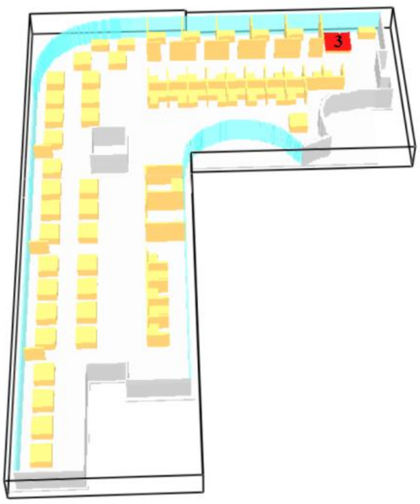
Input New Zealand approach C/VM2

Parameter	
Soot yield, y_s	0.07 kg/kg_{fuel}
CO yield, y_{CO}	0.04 kg/kg_{fuel}
CO_2 yield, y_{CO2}	1.5 kg/kg_{fuel}
Heat of Combustion, ΔH_c	20 MJ/kg_{fuel}
Radiative Fraction	35% radiative absorption
Location of fire above floor	0.5 m (low height to give maximum air entrainment)
Fire Growth Rate(s) Q	$0.0469t^2$
Peak Heat Release Rate	20 MW
HRRPUA	675 kW/m^2

Locations fire







FDS input file

- FDS 6.1.2 Input file for C/VM2: standard scenario, heat and smoke control and sprinklers activation.
- FDS Input file for Belgian scenarios: PBD and prescriptive

1. FDS 6.1.2 Input file for C/VM2: standard scenario, heat and smoke control and sprinklers activation.

```
&HEAD CHID                         ='NZ_ZONE1_NOWALLS'                                    /
&TIME T_END                        = 600/
&DUMP RENDER_FILE        ='NZ_ZONE1_NOWALLS', DT_RESTART=100.0/
&SPEC ID='CARBON MONOXIDE'/
&SPEC ID='SOOT'/
&MESH ID='Mesh01', IJK=90,180,16, XB=0.0,18.0,0.0,36.0,0.0,3.2/
&MESH ID='Mesh02', IJK=90,125,16, XB=0.0,18.0,36.0,61.0,0.0,3.2/
&MESH ID='Mesh03', IJK=120,108,16, XB=18.0,42.0,39.0,60.6,0.0,3.2/
&REAC ID='Reaction2',
    FYI='Reaction',
    FUEL='REAC_FUEL',
    C=0.63
    H=4.76,
    O=1.1,
    N=0.0,
    CO_YIELD=0.04,
    SOOT_YIELD=0.07
            HEAT_OF_COMBUSTION= 20000/
&SURF ID='Fire',
    COLOR='RED',
    HRRPUA=675.35,
    RAMP_Q='Fire_RAMP_Q'/
&RAMP ID='Fire_RAMP_Q', T=0.0,             F=0.0      /
&RAMP ID='Fire_RAMP_Q', T=60.0,      F=0.028   /
&RAMP ID='Fire_RAMP_Q', T=120.0,     F=0.111   /
&RAMP ID='Fire_RAMP_Q', T=180.0,     F=0.250   /
&RAMP ID='Fire_RAMP_Q', T=240.0,     F=0.444/
&RAMP ID='Fire_RAMP_Q', T=300.0,     F=0.694   /
&RAMP ID='Fire_RAMP_Q', T=360.0,     F=1       /
&RAMP ID='Fire_RAMP_Q', T=600.0,     F=1       /
&OBST XB=13.6,16.6,30.2,33.2,0.0,0.5, SURF_IDS='Fire','INERT','INERT'/ Fire Room
&MATL ID='CONCRETE',
    FYI='NBSIR 88-3752 - ATF NIST Multi-Floor Validation',
    SPECIFIC_HEAT=1.04,
    CONDUCTIVITY=1.8,
    DENSITY=2280.0/
&MATL ID='Glass',
    FYI='Glass',
    SPECIFIC_HEAT=0.8,
    CONDUCTIVITY=0.8,
    DENSITY=2500.0,
    EMISSIVITY=0.91/
&SURF ID='CONCRETE',
    COLOR='GRAY 80',
    MATL_ID(1,1)='CONCRETE',
    MATL_MASS_FRACTION(1,1)=1.0,
    THICKNESS(1)=0.4/
&SURF ID='Glass',
    RGB=0,204,204,
    MATL_ID(1,1)='Glass',
    MATL_MASS_FRACTION(1,1)=1.0,
    THICKNESS(1)=0.05/
SURF ID='HVAC extraction',
    RGB=51,51,255,
    VOLUME_FLUX=0.14,
    TAU_V=60.0
&OBST XB=1.0,3.0,28.2,28.4,0.0,2.2, SURF_ID='INERT'/ inside wall
```

```
&OBST XB=1.00007,3.00007,41.4586,41.6586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=1.00007,3.00007,15.0586,15.2586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,13.2,16.2,27.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,16.2,16.4,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,18.4,18.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,20.6,20.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,22.8,23.0,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,25.0,25.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,35.6,50.6,50.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,31.2,50.4,50.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=31.0,31.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=35.4,35.6,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=22.2,22.4,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=20.0,20.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.8,18.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=15.6,15.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=16.0,19.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=20.0,22.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=23.8,27.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=28.0,31.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=32.0,35.2,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=36.2,37.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.4,33.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=37.6,37.8,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=25.4,25.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=29.4,29.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=21.4,21.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.3704,17.5704,55.963,59.763,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,7.2,0.8,1.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=13.0,13.2,33.6,35.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,17.2,33.6,33.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=11.8,40.6,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=40.4,40.6,47.6,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=36.6,40.6,47.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,10.4,37.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.2,7.4,0.6,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,12.2,36.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=10.8,17.6,10.0,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,36.0,37.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.8,37.8,38.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,18.0,38.8,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,38.4,39.4,47.4,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,40.8,47.4,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=20.6,40.8,60.0,60.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,7.4,0.6,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,12.2,36.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=10.8,17.6,10.0,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,36.0,37.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.8,37.8,38.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,18.0,38.8,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,38.4,39.4,47.4,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,40.8,47.4,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=20.6,40.8,60.0,60.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=28.8,29.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.2,33.4,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=26.6,26.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=24.4,24.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,15.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=7.2,7.4,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,39.0,39.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,43.0,43.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=11.0,11.2,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=13.0,13.2,36.2,37.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,17.2,37.2,37.4,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,1.0,1.0,36.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.6,1.0,50.2,50.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,36.0,50.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,50.8,51.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.2,51.4,52.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.2,52.0,52.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.4,52.8,53.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.2,1.4,53.6,53.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.2,1.6,53.8,54.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.6,54.2,54.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.8,54.4,54.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,1.8,54.6,54.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,2.0,54.8,55.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.0,55.0,55.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.2,55.2,55.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=2.2,2.6,56.0,56.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.6,56.2,56.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.8,56.4,56.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.0,56.6,56.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.2,56.8,57.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.0,3.4,57.0,57.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.2,3.6,57.2,57.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.4,3.8,57.4,57.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.6,4.2,57.6,57.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.8,4.4,57.8,58.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.2,4.6,58.0,58.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.4,4.8,58.2,58.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.6,5.2,58.4,58.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.0,5.8,58.6,58.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.4,6.4,58.8,59.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.0,7.0,59.0,59.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.6,7.8,59.2,59.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=7.2,8.8,59.4,59.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=8.2,10.4,59.6,59.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=9.2,11.8,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=39.4,39.6,49.6,53.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.4,49.4,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.6,53.6,53.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=40.4,40.6,53.8,59.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,37.4,38.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.2,39.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.4,17.6,39.4,40.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.6,17.8,40.2,40.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.8,18.0,40.4,40.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.0,38.2,0.0,0.0, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.0,38.2,3.2,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.0,18.2,40.6,41.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.2,18.4,41.0,41.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=18.4,18.8,41.4,41.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.6,19.0,41.6,41.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.8,19.2,41.8,42.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.0,19.4,42.0,42.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.2,19.6,42.2,42.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.6,20.0,42.4,42.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.0,20.4,42.6,42.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.4,20.8,42.8,43.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.8,21.4,43.0,43.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=21.2,22.0,43.2,43.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=21.8,24.6,43.4,43.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=24.6,25.6,43.2,43.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=26.2,26.8,42.8,43.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=28.0,28.2,41.8,42.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.2,28.4,41.6,41.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.4,28.6,41.4,41.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=28.8,29.0,40.8,41.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=29.2,29.6,40.2,40.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.4,29.8,40.0,40.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.6,29.8,39.8,40.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.8,30.0,39.6,39.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID6='Glass','CONCRETE','Glass','Glass','CONCRETE','CONCRETE'/ wall
&OBST XB=30.0,30.4,39.4,39.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.0,30.8,39.6,39.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.2,31.2,39.8,40.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.6,31.6,40.0,40.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=31.0,32.0,40.2,40.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=31.4,32.6,40.4,40.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.0,33.0,40.6,40.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.2,32.6,43.6,45.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.2,32.8,45.2,45.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,32.8,42.4,43.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,32.8,45.4,45.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,33.0,45.8,46.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,33.2,40.8,41.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.0,41.6,42.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.0,46.0,46.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.2,41.4,41.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.2,46.2,46.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.8,33.2,41.0,41.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.8,33.4,46.4,46.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=33.0,33.6,46.6,46.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
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&OBST XB=33.4,34.6,47.0,47.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=33.8,35.8,47.2,47.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=34.4,36.6,47.4,47.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=35.8,36.6,47.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,7.2,0.8,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,11.2,12.4,12.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,11.2,10.6,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,17.2,10.4,10.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=2.0,4.0,1.0,2.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,3.0,5.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,6.0,8.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,12.0,14.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,9.0,11.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=17.6,18.0,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=18.0,19.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=21.6,23.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=25.6,27.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=33.8,35.8,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=29.6,31.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=38.0,40.0,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,29.4,31.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,32.6,34.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,35.4,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,36.0,37.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,29.4,31.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,32.6,34.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,38.4,40.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,35.4,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,36.0,37.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,16.2,18.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,19.2,21.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,25.2,27.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,22.2,24.2,0.2,1.2, SURF_ID='INERT'/ tables
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&OBST XB=2.0,4.0,16.2,18.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,19.2,21.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,25.2,27.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,22.2,24.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,48.6,50.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,51.6,53.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,45.8,47.8,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,42.6,44.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,48.6,50.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,45.8,47.8,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,51.6,53.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=9.0,11.0,54.6,56.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=5.0,7.0,54.6,56.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=7.0,9.0,57.6,58.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=10.0,12.0,57.6,58.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=13.6,15.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=29.0,31.0,44.2,46.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=15.8,17.0,35.2,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=15.8,17.0,36.0,37.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=13.2,14.2,17.4,19.6,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,14.2,21.8,24.0,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,14.2,26.2,27.2,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,16.2,17.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,19.6,21.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,24.0,26.2,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,14.6,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,14.6,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,18.0,49.4,51.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=16.8,18.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=16.8,18.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,19.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,19.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,31.0,49.4,50.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,35.4,50.8,51.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=21.2,23.4,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=21.2,23.4,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=24.4,25.6,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=24.6,25.6,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=27.8,30.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=27.8,30.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=32.2,34.4,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&HOLE XB=7.0,7.2,2.2,3.2,0.2,0.4/ hole under door
&HOLE XB=37.8,38.8,47.6,47.8,0.2,0.4/ hole under door
&VENT MB='XMIN', SURF_ID='OPEN'  /
&VENT MB='XMAX', SURF_ID='OPEN'  /
&VENT MB='YMIN', SURF_ID='OPEN'  /
&VENT MB='YMAX', SURF_ID='OPEN'  /
&VENT MB='ZMIN', SURF_ID='OPEN'  /
&VENT MB='ZMAX', SURF_ID='OPEN'  /
&PROP ID='Cleary Photoelectric P1',
    QUANTITY='CHAMBER OBSCURATION',
    ACTIVATION_OBSCURATION=3.3,
    ALPHA_E=1.8,
    BETA_E=-1.0,
    ALPHA_C=1.0,
    BETA_C=-0.8/
&DEVC ID='SD01', PROP_ID='Cleary Photoelectric P1', XYZ=15.1,31.7,2.9/
&DEVC ID='SD02', PROP_ID='Cleary Photoelectric P1', XYZ=14.1,31.7,2.9/
&DEVC ID='SD03', PROP_ID='Cleary Photoelectric P1', XYZ=13.1,31.7,2.9/
&DEVC ID='SD04', PROP_ID='Cleary Photoelectric P1', XYZ=12.1,31.7,2.9/
&DEVC ID='SD05', PROP_ID='Cleary Photoelectric P1', XYZ=11.1,31.7,2.9/
&DEVC ID='SD06', PROP_ID='Cleary Photoelectric P1', XYZ=10.1,31.7,2.9/
&DEVC ID='SD07', PROP_ID='Cleary Photoelectric P1', XYZ=9.1,31.7,2.9/
&SLCF QUANTITY='TEMPERATURE',                                        PBZ=2.2/
&SLCF QUANTITY='VISIBILITY',                                         PBZ=2.2/
&SLCF QUANTITY='VELOCITY', VECTOR=.TRUE.,                       PBZ=2.2/
&SLCF QUANTITY='EXTINCTION COEFFICIENT',                        PBZ=2.2/
&SLCF QUANTITY='PRESSURE',
          PBZ=2.2/
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT',                       PBZ=2.2/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='CARBON MONOXIDE',PBZ=2.2/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='CARBON DIOXIDE', PBZ=2.2/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='OXYGEN',        PBZ=2.2/
&SLCF QUANTITY='TEMPERATURE',                                        PBZ=2.6/
&SLCF QUANTITY='VELOCITY', VECTOR=.TRUE.,                       PBZ=2.6/
&SLCF QUANTITY='PRESSURE',
          PBZ=2.6/
&SLCF QUANTITY='EXTINCTION COEFFICIENT',                        PBZ=2.6/
&SLCF QUANTITY='VISIBILITY',                                         PBZ=2.6/
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT',                  PBZ=2.6/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='CARBON MONOXIDE',   PBZ=2.6/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='CARBON DIOXIDE',    PBZ=2.6/
&SLCF QUANTITY='VOLUME FRACTION', SPEC_ID='OXYGEN',        PBZ=2.6/
Heat and smoke control
&DEVC ID='Klockfalse-A' ,XYZ=1,1,1, QUANTITY='TIME', SETPOINT=30, INITIAL_STATE=.FALSE. &SURF ID='FAN', 
COLOR='GREEN', VOLUME_FLOW= 10 /  m³/s
```

```
&OBST XB=8.6,9.6,39,39.4,1.8,2.8, SURF_ID6='CONCRETE','CONCRETE','FAN','CONCRETE','CONCRETE', 'CONCRETE',
DEVC_ID='Klockfalse-A' / FAN
SPRINKLER ACTIVATION
&SPEC ID='Water_SPEC',
        MW=29 ,
        DENSITY_LIQUID=1000,
        SPECIFIC_HEAT_LIQUID=4.184,
        VAPORIZATION_TEMPERATURE=100,
        MELTING_TEMPERATURE=0,
        HEAT_OF_VAPORIZATION=2259/
&PART ID='Water',
        SPEC_ID='Water_SPEC'
        DIAMETER=500
        DISTRIBUTION='ROSIN-RAMMLER'
        COLOR = 'BLUE'
        AGE=60/
&PROP ID = 'sprinkler'
        QUANTITY='SPRINKLER LINK TEMPERATURE'
        ACTIVATION_TEMPERATURE= 68
        RTI=135
        C_FACTOR=0.85
        PART_ID='Water'
        FLOW_RATE=1
        PARTICLE_VELOCITY=5.0/
&DEVC ID='S1', PROP_ID='sprinkler', XYZ= 15.1,31.7,2.9/
&DEVC ID='S2', PROP_ID='sprinkler', XYZ= 14.1,31.7,2.9/
&DEVC ID='S3', PROP_ID='sprinkler', XYZ= 13.1,31.7,2.9/
&DEVC ID='S4', PROP_ID='sprinkler', XYZ= 12.1,31.7,2.9/
&DEVC ID='S5', PROP_ID='sprinkler', XYZ= 11.1,31.7,2.9/
&DEVC ID='S6', PROP_ID='sprinkler', XYZ= 10.1,31.7,2.9/
&DEVC ID='S7', PROP_ID='sprinkler', XYZ= 9.1,31.7,2.9/
&TAIL /
```

2. FDS Input file for Belgian scenarios: PBD and prescriptive

```
&HEAD CHID        ='PBD_ZONE1_NOWALLS_95'                                  /
&TIME T_END       = 600.0                                                        /
&DUMP RENDER_FILE='PBD_ZONE1_NOWALLS_95', DT_RESTART=100.0, NFRAMES=120/
&SPEC ID='CARBON MONOXIDE'/
&SPEC ID='SOOT'/
&MESH ID='Mesh01', IJK=90,180,16, XB=0.0,18.0,0.0,36.0,0.0,3.2/
&MESH ID='Mesh02', IJK=90,125,16, XB=0.0,18.0,36.0,61.0,0.0,3.2/
&MESH ID='Mesh03', IJK=120,108,16, XB=18.0,42.0,39.0,60.6,0.0,3.2/
&REAC ID='Reaction2',
    FYI='Reaction',
    FUEL='REAC_FUEL',
    C=6.3,
    H=7.1,
    O=2.1,
    N=1.0,
    CO_YIELD=0.14,
    SOOT_YIELD=0.19/
&SURF ID='Fire',
    COLOR='RED',
    HRRPUA=426.68,
    RAMP_Q='Fire_RAMP_Q'/
&RAMP ID='Fire_RAMP_Q', T=0.0,              F=0.0     /
&RAMP ID='Fire_RAMP_Q', T=60.0,      F=0.028   /
&RAMP ID='Fire_RAMP_Q', T=120.0,     F=0.111   /
&RAMP ID='Fire_RAMP_Q', T=180.0,     F=0.250   /
&RAMP ID='Fire_RAMP_Q', T=240.0,     F=0.444/
&RAMP ID='Fire_RAMP_Q', T=300.0,     F=0.694   /
&RAMP ID='Fire_RAMP_Q', T=360.0,     F=1       /
&RAMP ID='Fire_RAMP_Q', T=600.0,     F=1       /
&OBST XB=14.0,16.2,30.6,32.8,0.0,1.0, SURF_IDS='Fire','INERT','INERT'/ Fire Room
&MATL ID='CONCRETE',
    FYI='NBSIR 88-3752 - ATF NIST Multi-Floor Validation',
    SPECIFIC_HEAT=1.04,
    CONDUCTIVITY=1.8,
    DENSITY=2280.0/
&MATL ID='Glass',
    FYI='Glass',
```

```
    SPECIFIC_HEAT=0.8,
    CONDUCTIVITY=0.8,
    DENSITY=2500.0,
    EMISSIVITY=0.91/
&SURF ID='CONCRETE',
    COLOR='GRAY 80',
    MATL_ID(1,1)='CONCRETE',
    MATL_MASS_FRACTION(1,1)=1.0,
    THICKNESS(1)=0.4/

&SURF ID='Glass',
    RGB=0,204,204,
    MATL_ID(1,1)='Glass',
    MATL_MASS_FRACTION(1,1)=1.0,
    THICKNESS(1)=0.05/
&OBST XB=1.0,3.0,28.2,28.4,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=1.00007,3.00007,41.4586,41.6586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=1.00007,3.00007,15.0586,15.2586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,13.2,16.2,27.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,16.2,16.4,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,18.4,18.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,20.6,20.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,22.8,23.0,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,15.2,25.0,25.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,35.6,50.6,50.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,31.2,50.4,50.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=31.0,31.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=35.4,35.6,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=22.2,22.4,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=20.0,20.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.8,18.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=15.6,15.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=16.0,19.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=20.0,22.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=23.8,27.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=28.0,31.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=32.0,35.2,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=36.2,37.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.4,33.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=37.6,37.8,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=25.4,25.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=29.4,29.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=21.4,21.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.3704,17.5704,55.963,59.763,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,7.2,0.8,1.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=13.0,13.2,33.6,35.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,17.2,33.6,33.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=11.8,40.6,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=40.4,40.6,47.6,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=36.6,40.6,47.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,10.4,37.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.2,7.4,0.6,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,12.2,36.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=10.8,17.6,10.0,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,36.0,37.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.8,37.8,38.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,18.0,38.8,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,38.4,39.4,47.4,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,40.8,47.4,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=20.6,40.8,60.0,60.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,7.4,0.6,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,12.2,36.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=10.8,17.6,10.0,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,36.0,37.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.8,37.8,38.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,18.0,38.8,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,38.4,39.4,47.4,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,40.8,47.4,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=20.6,40.8,60.0,60.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=28.8,29.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.2,33.4,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=26.6,26.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=24.4,24.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,15.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=7.2,7.4,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,39.0,39.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,43.0,43.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=11.0,11.2,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=13.0,13.2,36.2,37.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.0,17.2,37.2,37.4,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,1.0,1.0,36.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.6,1.0,50.2,50.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,36.0,50.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,50.8,51.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.2,51.4,52.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.2,52.0,52.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.4,52.8,53.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.2,1.4,53.6,53.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
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&OBST XB=1.2,1.6,53.8,54.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.6,54.2,54.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.8,54.4,54.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,1.8,54.6,54.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,2.0,54.8,55.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.0,55.0,55.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.2,55.2,55.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.0,2.2,55.4,55.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.0,2.4,55.6,55.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.2,2.4,55.8,56.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.2,2.6,56.0,56.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.6,56.2,56.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.8,56.4,56.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.0,56.6,56.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.2,56.8,57.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.0,3.4,57.0,57.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.2,3.6,57.2,57.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.4,3.8,57.4,57.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.6,4.2,57.6,57.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.8,4.4,57.8,58.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.2,4.6,58.0,58.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.4,4.8,58.2,58.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.6,5.2,58.4,58.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.0,5.8,58.6,58.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.4,6.4,58.8,59.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.0,7.0,59.0,59.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.6,7.8,59.2,59.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=7.2,8.8,59.4,59.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=8.2,10.4,59.6,59.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=9.2,11.8,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=39.4,39.6,49.6,53.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.4,49.4,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.6,53.6,53.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=40.4,40.6,53.8,59.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,37.4,38.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.2,39.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.4,17.6,39.4,40.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.6,17.8,40.2,40.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.8,18.0,40.4,40.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.0,38.2,0.0,0.0, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=17.2,17.4,38.0,38.2,3.2,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.0,18.2,40.6,41.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.2,18.4,41.0,41.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.4,18.6,41.2,41.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.4,18.8,41.4,41.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.6,19.0,41.6,41.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=18.8,19.2,41.8,42.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.0,19.4,42.0,42.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.2,19.6,42.2,42.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=19.6,20.0,42.4,42.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.0,20.4,42.6,42.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.4,20.8,42.8,43.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=20.8,21.4,43.0,43.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=21.2,22.0,43.2,43.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=21.8,24.6,43.4,43.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=24.6,25.6,43.2,43.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=25.6,26.2,43.0,43.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=26.2,26.8,42.8,43.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=26.8,27.2,42.6,42.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=27.0,27.4,42.4,42.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=27.4,27.8,42.2,42.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=27.8,28.0,42.0,42.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.0,28.2,41.8,42.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.2,28.4,41.6,41.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.4,28.6,41.4,41.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.4,28.8,41.2,41.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.6,29.0,41.0,41.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=28.8,29.0,40.8,41.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.0,29.2,40.6,40.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.2,29.4,40.4,40.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.2,29.6,40.2,40.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.4,29.8,40.0,40.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.6,29.8,39.8,40.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=29.8,30.0,39.6,39.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID6='Glass','CONCRETE','Glass','Glass','CONCRETE','CONCRETE'/ wall
&OBST XB=30.0,30.4,39.4,39.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.0,30.8,39.6,39.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.2,31.2,39.8,40.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=30.6,31.6,40.0,40.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=31.0,32.0,40.2,40.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=31.4,32.6,40.4,40.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.0,33.0,40.6,40.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.2,32.6,43.6,45.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.2,32.8,45.2,45.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,32.8,42.4,43.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,32.8,45.4,45.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,33.0,45.8,46.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.4,33.2,40.8,41.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.0,41.6,42.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.0,46.0,46.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.2,41.4,41.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.6,33.2,46.2,46.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.8,33.2,41.0,41.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=32.8,33.4,46.4,46.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=33.0,33.6,46.6,46.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=33.2,33.8,46.8,47.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
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&OBST XB=33.4,34.6,47.0,47.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=33.8,35.8,47.2,47.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=34.4,36.6,47.4,47.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=35.8,36.6,47.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,7.2,0.8,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,11.2,12.4,12.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,11.2,10.6,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,17.2,10.4,10.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=2.0,4.0,1.0,2.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,3.0,5.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,6.0,8.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,12.0,14.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,9.0,11.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=17.6,18.0,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=18.0,19.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=21.6,23.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=25.6,27.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=33.8,35.8,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=29.6,31.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=38.0,40.0,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,29.4,31.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,32.6,34.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,35.4,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,36.0,37.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,29.4,31.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,32.6,34.6,0.2,1.2, SURF_ID='INERT'/ tables
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&OBST XB=2.0,4.0,35.4,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,36.0,37.4,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,16.2,18.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,19.2,21.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,25.2,27.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,22.2,24.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,16.2,18.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,19.2,21.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,25.2,27.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,22.2,24.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,48.6,50.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,51.6,53.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,45.8,47.8,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=2.0,4.0,42.6,44.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,48.6,50.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,45.8,47.8,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=6.0,8.0,51.6,53.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=9.0,11.0,54.6,56.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=5.0,7.0,54.6,56.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=7.0,9.0,57.6,58.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=10.0,12.0,57.6,58.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=13.6,15.6,58.6,59.6,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=29.0,31.0,44.2,46.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=15.8,17.0,35.2,36.0,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=15.8,17.0,36.0,37.2,0.2,1.2, SURF_ID='INERT'/ tables
&OBST XB=13.2,14.2,17.4,19.6,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,14.2,21.8,24.0,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,14.2,26.2,27.2,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,16.2,17.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,19.6,21.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.2,15.2,24.0,26.2,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,14.6,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,14.6,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=13.6,18.0,49.4,51.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=16.8,18.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=16.8,18.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,19.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,19.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,31.0,49.4,50.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=18.0,35.4,50.8,51.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=21.2,23.4,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=21.2,23.4,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=24.4,25.6,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=24.6,25.6,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=27.8,30.0,48.4,49.4,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=27.8,30.0,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&OBST XB=32.2,34.4,51.8,52.8,0.0,1.0, SURF_ID='INERT'/ table
&HOLE XB=7.0,7.2,2.2,3.2,0.2,0.4/ hole under door
&HOLE XB=37.8,38.8,47.6,47.8,0.2,0.4/ hole under door
&OBST XB=1.0,3.0,28.2,28.4,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=1.00007,3.00007,41.4586,41.6586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=1.00007,3.00007,15.0586,15.2586,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,12.2,16.2,27.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,14.2,16.2,16.4,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,14.2,18.4,18.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,14.2,20.6,20.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,14.2,22.8,23.0,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=12.0,14.2,25.0,25.2,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,35.6,50.6,50.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,31.2,50.4,50.6,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=31.0,31.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=35.4,35.6,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=22.2,22.4,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=20.0,20.2,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.8,18.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=15.6,15.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=16.0,19.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
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&OBST XB=20.0,22.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=23.8,27.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=28.0,31.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=32.0,35.2,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=36.2,37.8,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.4,33.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=37.6,37.8,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=25.4,25.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=29.4,29.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=21.4,21.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=17.3704,17.5704,55.963,59.763,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,7.2,0.8,1.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.8,12.0,33.6,35.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=11.8,15.8,33.6,33.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=11.8,40.6,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=37.6,37.8,46.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=37.8,40.6,47.6,47.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=40.4,40.6,47.6,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,10.4,37.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.2,7.4,0.6,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,12.2,36.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=10.8,17.6,10.0,12.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.6,36.0,37.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,17.8,37.8,38.8,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,18.0,38.8,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,38.4,39.4,47.4,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=18.0,40.8,47.4,60.0,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=20.6,40.8,60.0,60.2,0.0,0.2, SURF_ID='CONCRETE'/ Floor
&OBST XB=0.2,7.4,0.6,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,12.2,36.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=10.8,17.6,10.0,12.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.6,36.0,37.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,17.8,37.8,38.8,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=0.2,18.0,38.8,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,38.4,39.4,47.4,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=18.0,40.8,47.4,60.0,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=20.6,40.8,60.0,60.2,3.0,3.2, RGB=240,240,240, TRANSPARENCY=0.101961, SURF_ID='CONCRETE'/ ceiling
&OBST XB=28.8,29.0,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=33.2,33.4,50.8,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=26.6,26.8,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=24.4,24.6,48.4,52.8,0.0,2.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,13.6,56.0,59.8,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=13.4,15.0,55.8,56.0,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=7.2,7.4,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,39.0,39.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=7.2,11.2,43.0,43.2,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=11.0,11.2,39.2,43.0,0.0,3.2, SURF_ID='CONCRETE'/ inside wall
&OBST XB=11.8,12.0,36.2,37.2,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=11.8,15.8,37.2,37.4,0.0,3.2, SURF_ID='INERT'/ inside wall
&OBST XB=0.8,1.0,1.0,36.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.6,1.0,50.2,50.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,36.0,50.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.0,50.8,51.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=0.8,1.2,51.4,52.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.2,52.0,52.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.0,1.4,52.8,53.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.2,1.4,53.6,53.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.2,1.6,53.8,54.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.6,54.2,54.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.4,1.8,54.4,54.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,1.8,54.6,54.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.6,2.0,54.8,55.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.0,55.0,55.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=1.8,2.2,55.2,55.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.0,2.2,55.4,55.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.0,2.4,55.6,55.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.2,2.4,55.8,56.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.2,2.6,56.0,56.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.6,56.2,56.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.4,2.8,56.4,56.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.0,56.6,56.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=2.6,3.2,56.8,57.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.0,3.4,57.0,57.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.2,3.6,57.2,57.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.4,3.8,57.4,57.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.6,4.2,57.6,57.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=3.8,4.4,57.8,58.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.2,4.6,58.0,58.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.4,4.8,58.2,58.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=4.6,5.2,58.4,58.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.0,5.8,58.6,58.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=5.4,6.4,58.8,59.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.0,7.0,59.0,59.2,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=6.6,7.8,59.2,59.4,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=7.2,8.8,59.4,59.6,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=8.2,10.4,59.6,59.8,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=9.2,11.8,59.8,60.0,0.0,3.2, RGB=102,255,255, TRANSPARENCY=0.6, SURF_ID='Glass'/ wall
&OBST XB=39.4,39.6,49.6,53.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.4,49.4,49.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=39.4,40.6,53.6,53.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=40.4,40.6,53.8,59.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=5.6,5.8,2.2,13.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=5.6,7.2,2.0,2.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=5.6,12.6,13.8,14.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,7.2,0.8,2.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
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&OBST XB=7.0,7.2,2.2,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=7.0,11.2,12.4,12.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,11.2,10.6,12.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=11.0,17.2,10.4,10.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=12.4,12.6,11.8,13.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=12.4,15.8,11.6,11.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=15.6,15.8,11.8,36.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=15.6,15.8,36.0,38.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=15.8,16.0,38.0,38.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=16.0,16.2,38.8,39.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=16.2,16.4,39.8,40.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=16.4,16.6,40.6,41.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=16.6,16.8,41.2,41.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=16.8,17.0,41.4,41.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.0,17.2,41.6,41.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.2,17.4,41.8,42.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.4,17.6,42.0,42.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.6,17.8,42.2,42.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=17.8,18.0,42.4,42.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.0,18.2,42.6,42.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.0,18.4,42.8,43.0,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.2,18.6,43.0,43.2,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.4,18.8,43.2,43.4,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.6,19.0,43.4,43.6,0.0,3.2, SURF_ID='CONCRETE'/ wall
&OBST XB=18.8,19.2,43.6,43.8,0.0,3.2, SURF_ID='CONCRETE'/ wall
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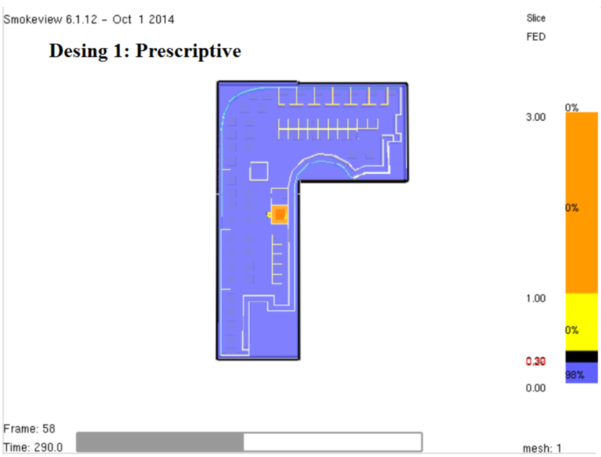
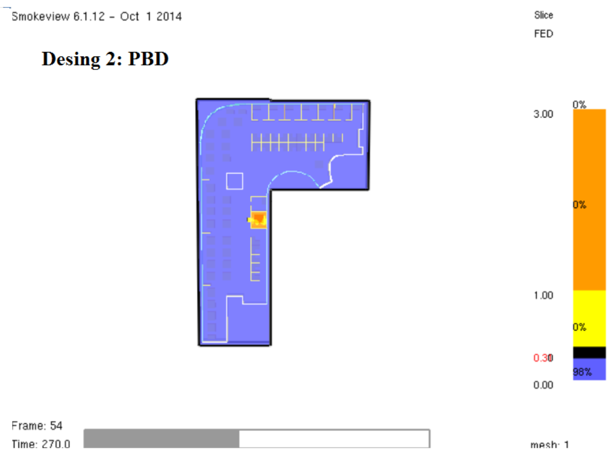
Slices FED Belgian approach

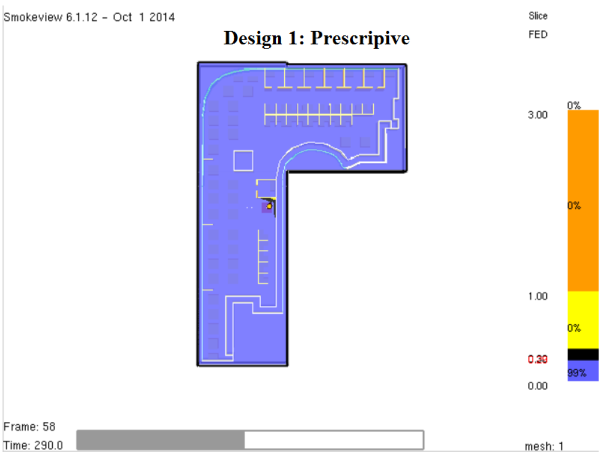
Location fire		Fractile	FED <0.3 (2m height)	
			Design 1: prescriptive	Design 2: PBD
Zone 1	Fire in room	95%	ok	ok
Zone 1	Fire not in room	95%	ok	ok
Zone 1	Fire in room	99%	ok	ok
Zone 1	Fire not in room	99%	ok	ok
Zone 2	Fire in room	95%	ok	ok
Zone 2	Fire not in room	95%	ok	ok
Zone 2	Fire in room	99%	ok	ok
Zone 2	Fire not in room	99%	ok	ok
Zone 3	Fire in room	95%	ok	ok
Zone 3	Fire not in room	95%	ok	ok
Zone 3	Fire in room	99%	Not ok	Not ok
Zone 3	Fire not in room	99%	Not ok	Not ok

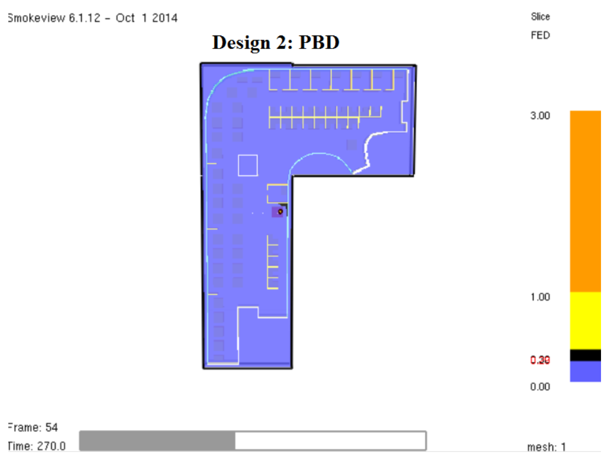
Fire in zone 1, in a room, 95% fractile input



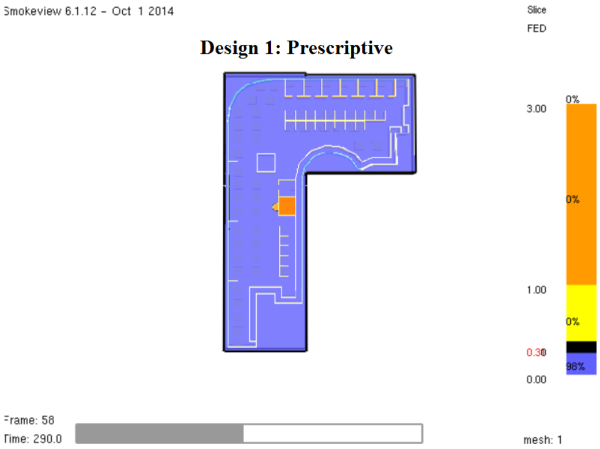


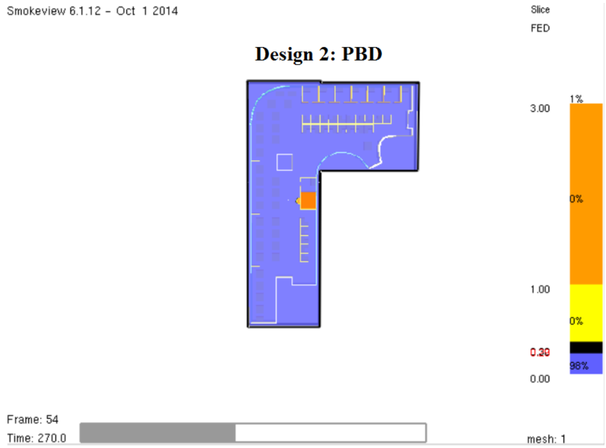
Fire in zone 1, not in a room, 95% fractile input



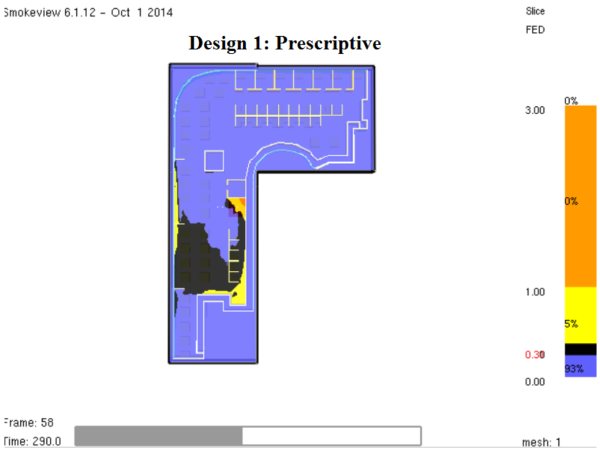


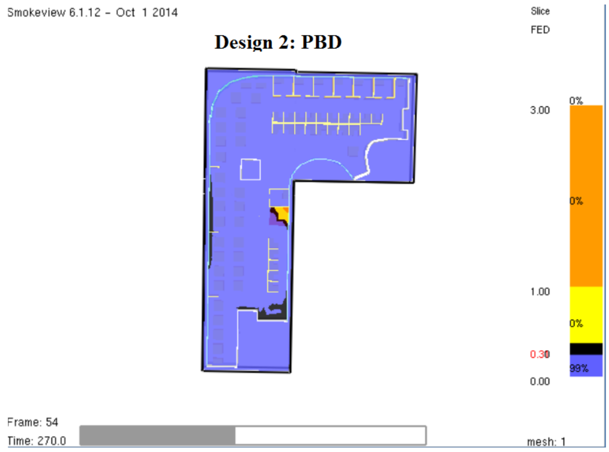
Fire in zone 1, in a room, 99% fractile input



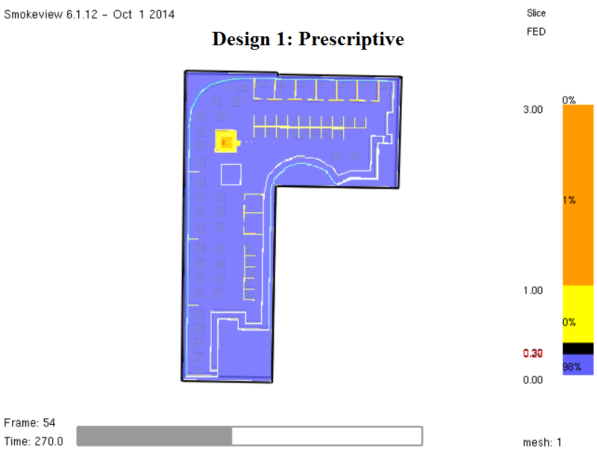


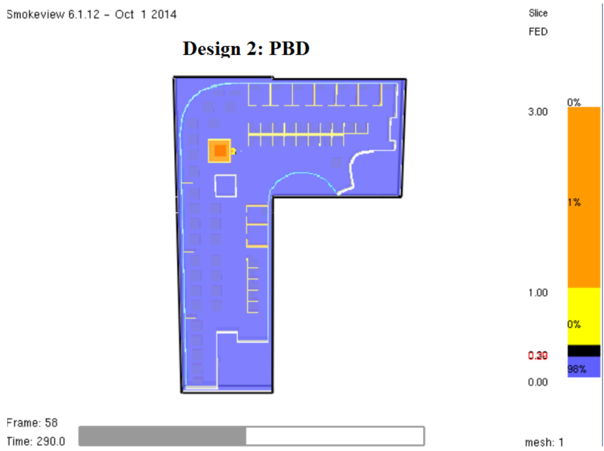
Fire in zone 1, not in room, 99% fractile input



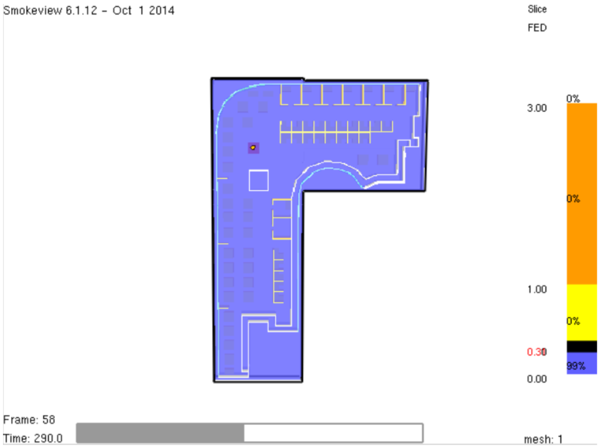


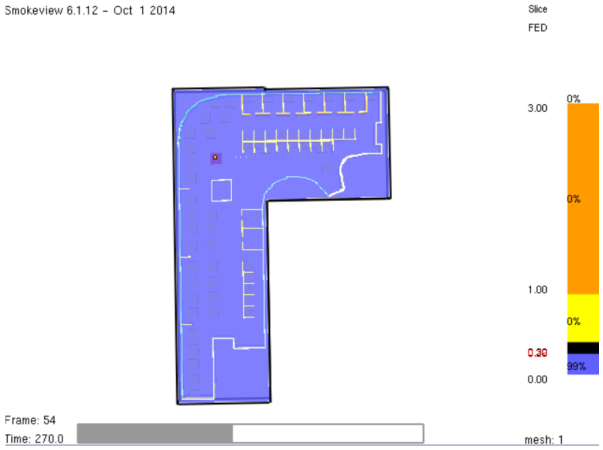
Fire in zone 2, in room, 95% fractile input



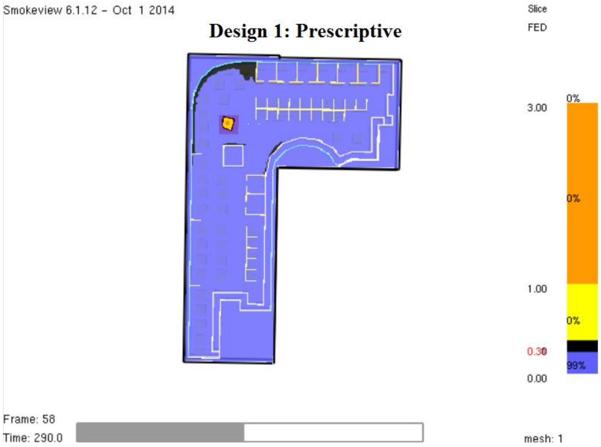


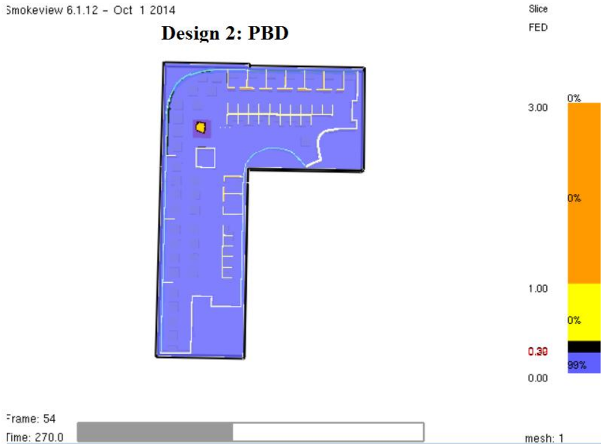
Fire in zone 2, not in room, 95% fractile input



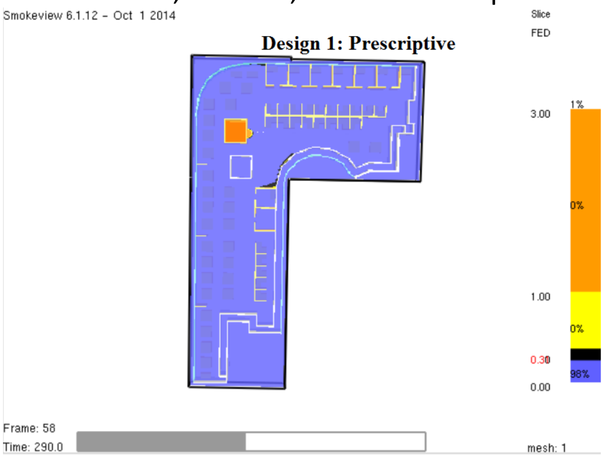


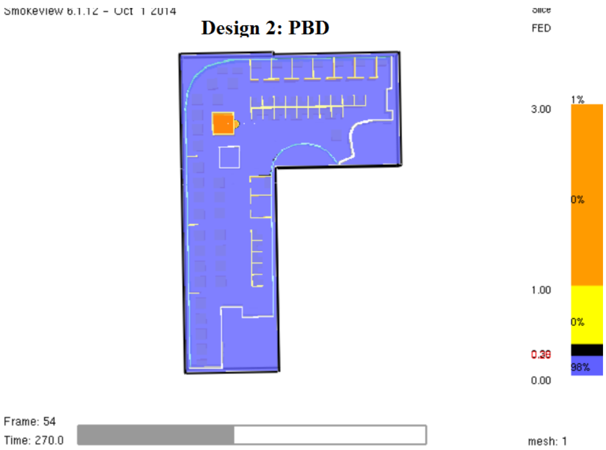
Fire in zone 2,not in room, 99% fractile input



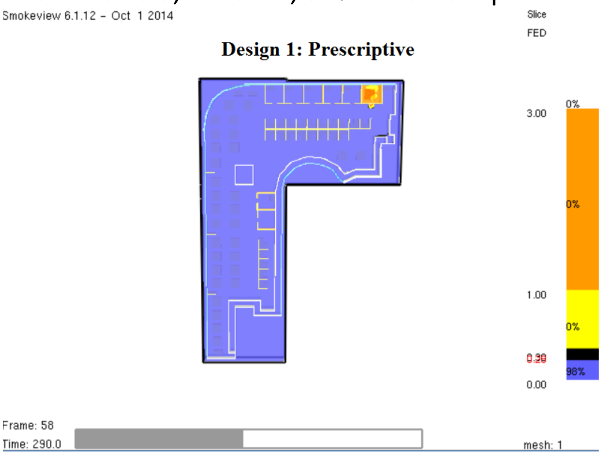


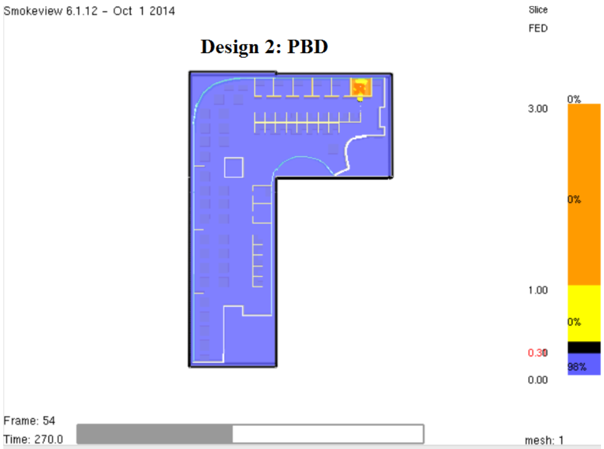
Fire in zone 2, in room, 99% fractile input



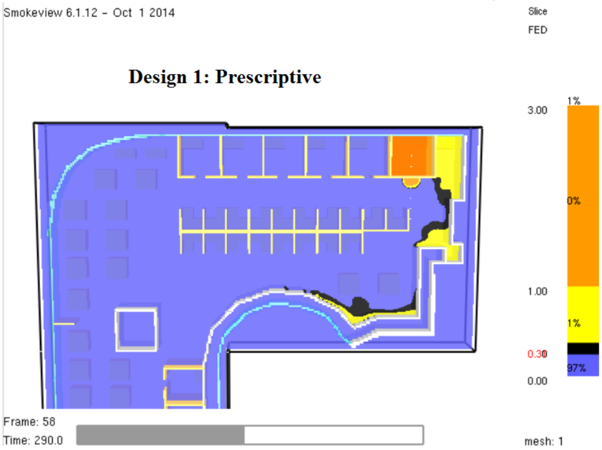


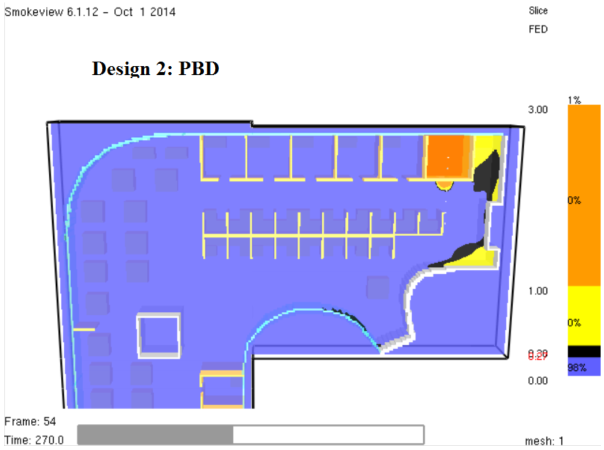
Fire in zone 3, in room, 95% fractile input



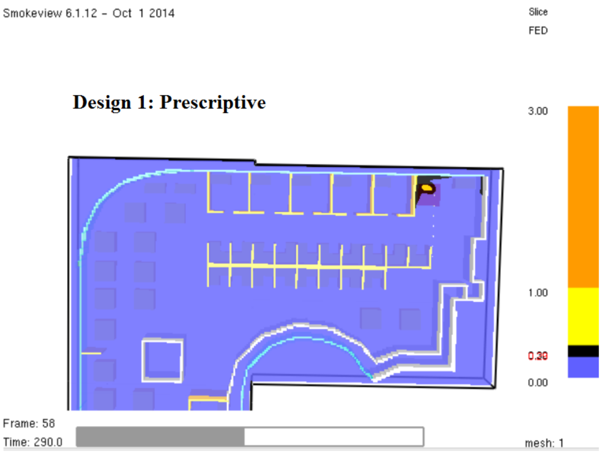


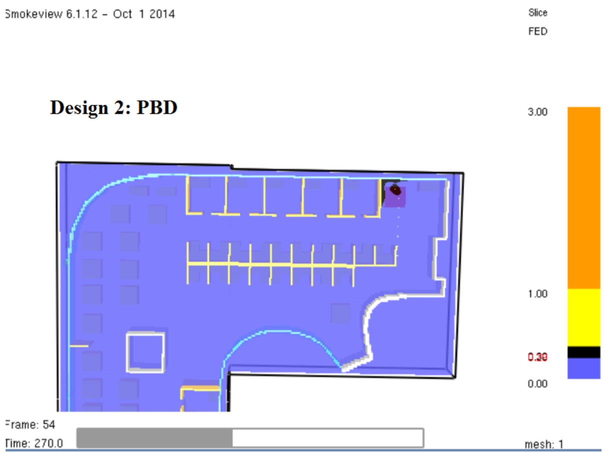
Fire in zone 3, in room, 99% fractile input



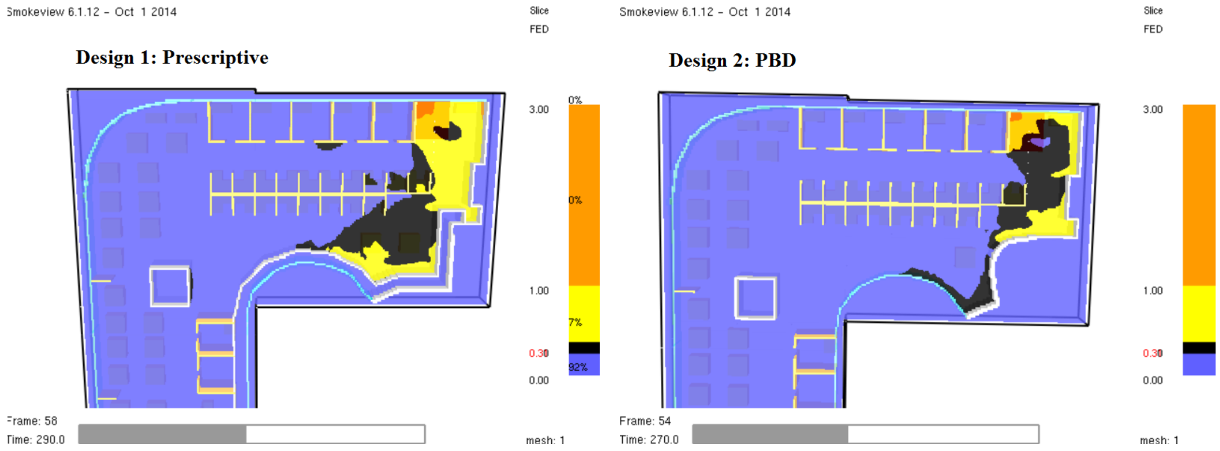


Fire in zone 3, not in a room, input 95%

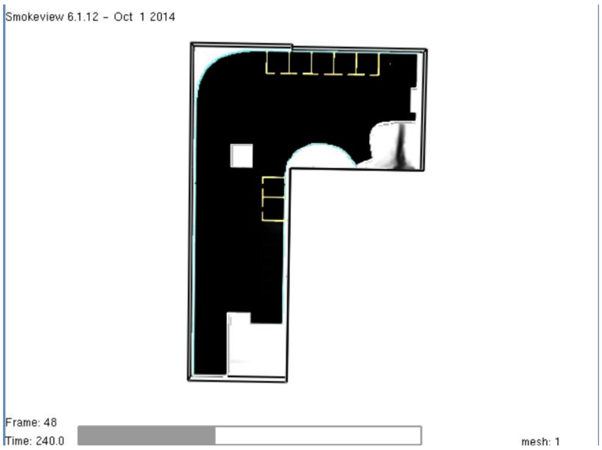




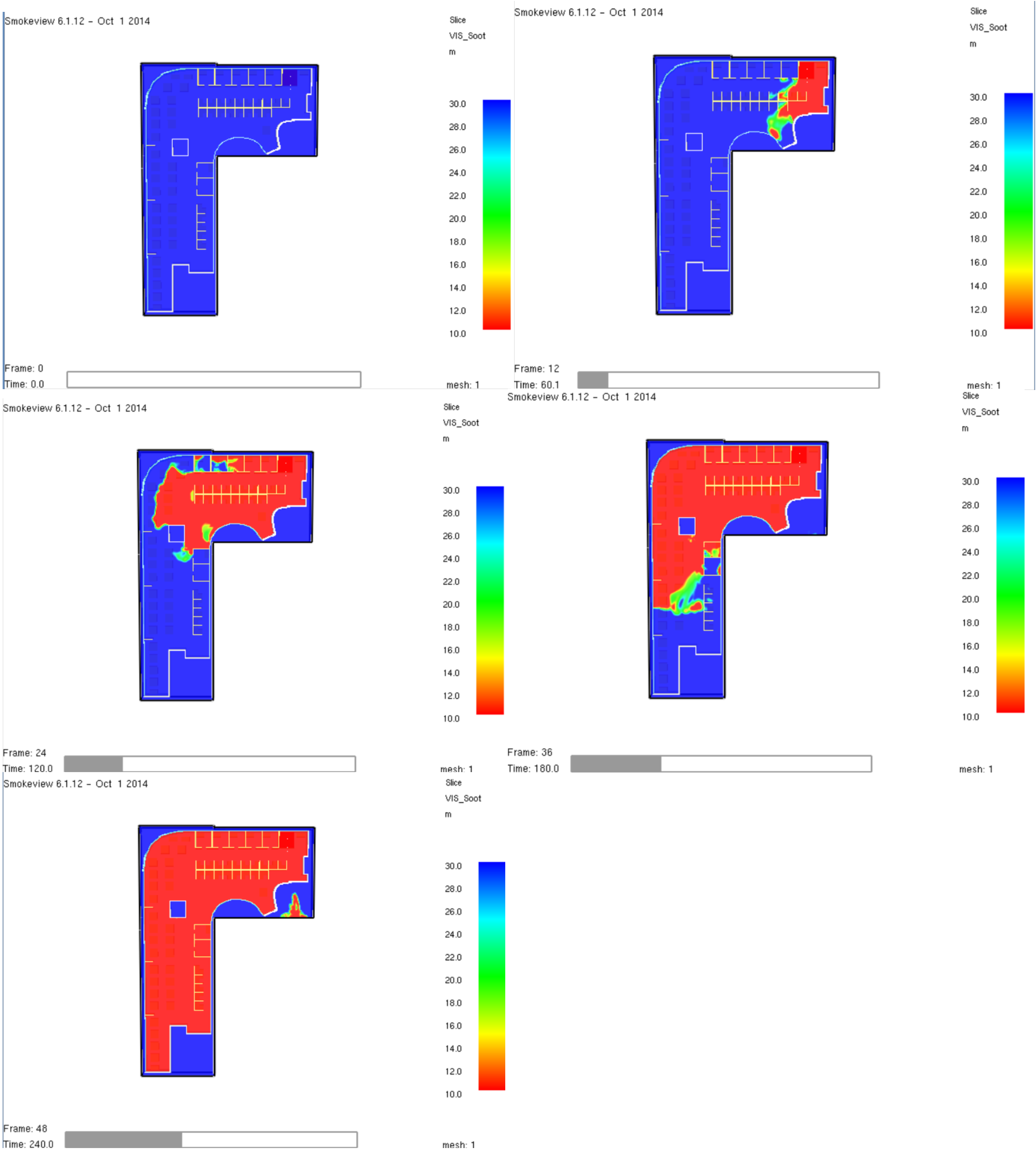
Fire in zone 3, not in a room, input 99%



Fire in zone 3, not a room, input 99% fractile: smoke spread 0s, 60s, 120s, 180s and 240s



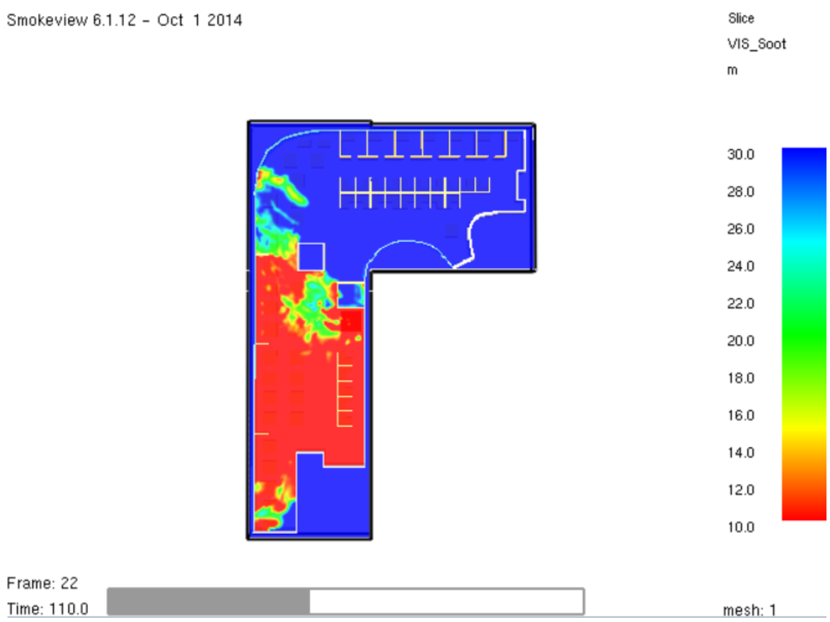
Fire in zone 3, not a room, input 99% fractile: Visibility (blue=30m, red =10m)
0s, 60s, 120s, 180s and 240s



Slices visibility New Zealand

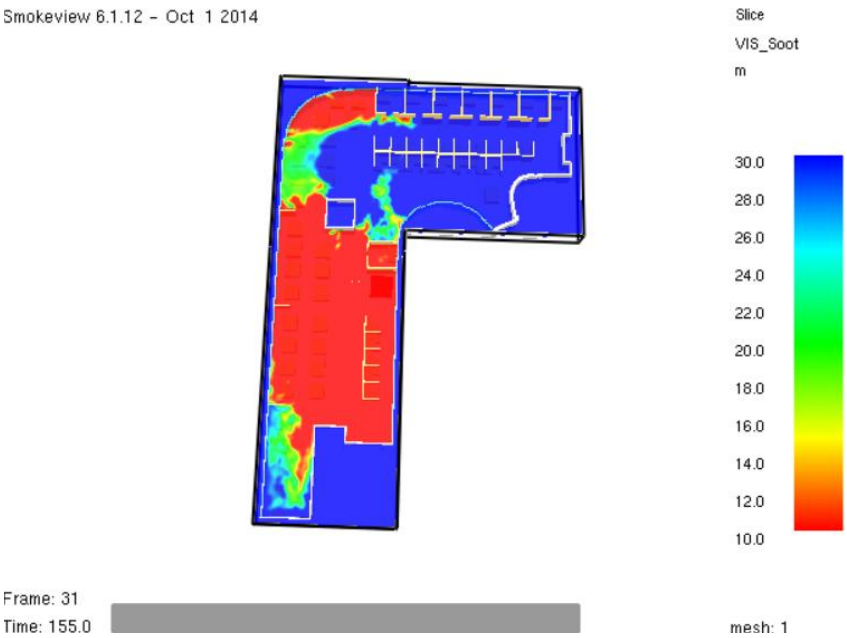
RSET		ASET	
t_{det}	30s		Visibility < 10m
t_{alarm}	30s	Zone 1, fire not in room	110s <131s
$t_{pre-movement}$	30s	Zone 1, fire in room	135s<131s
$t_{movement}$	2 exits:46s 1 exit: 91s	Zone 1, fire not in room, **with extraction**	155s > 131s
TOTAL RSET 2 exits used: 136s 1 exit used : 181s		Zone 2, fire not in room	120s <131s
		Zone 2, fire in room	130s <131s
		Zone 2, fire not in room, **with extraction**	205s>131s
		Zone 3, fire not in room	220s >181s
		Zone 3, fire in room	235s >181s
		Zone 3, fire not in room, **with extraction**	+300s>181s

Zone 1, fire not in room

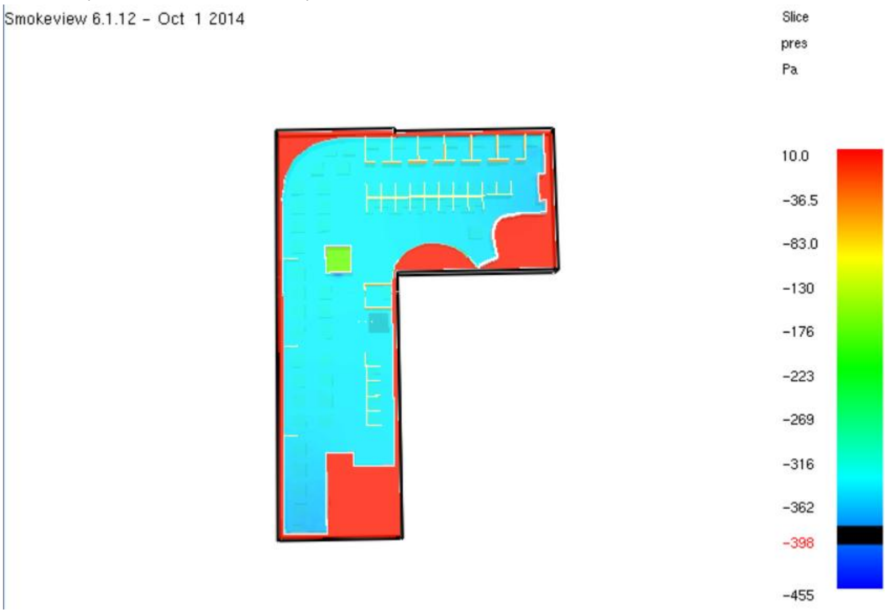


Zone 1, fire in room

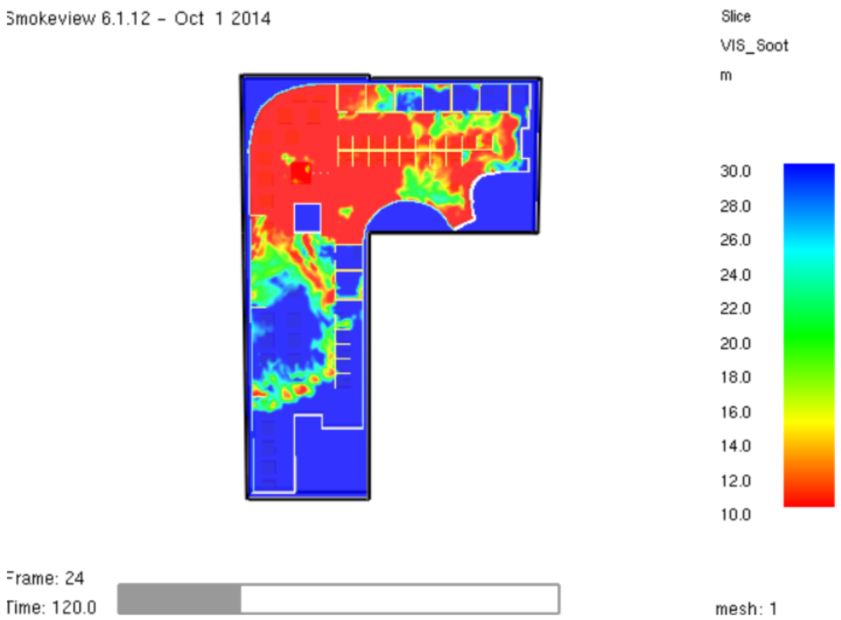
Zone 1, fire not in room, **with extraction**



Zone 1, With extraction, Pressure slice

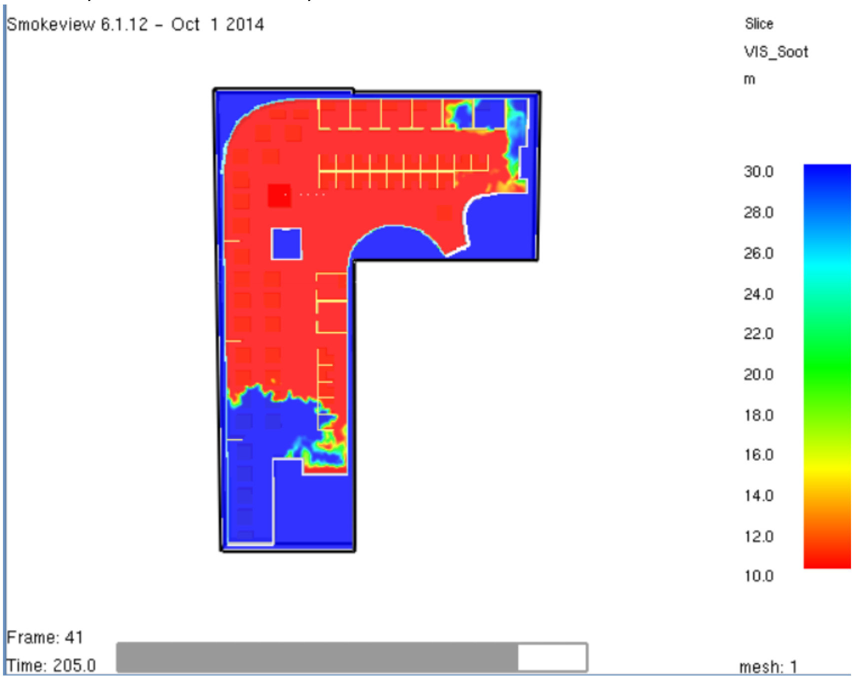


Zone 2, fire not in room

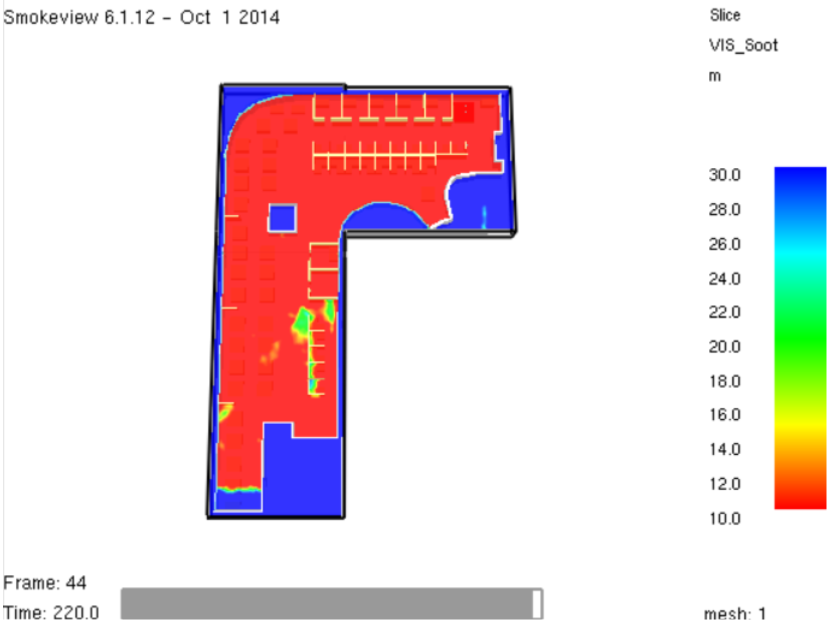


Zone 2, fire in room

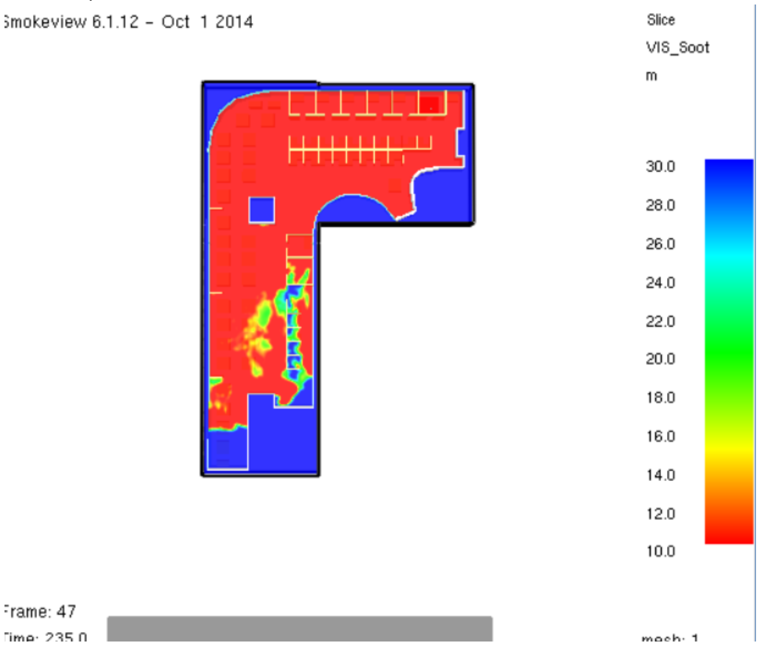
Zone 2, fire not in room, **with extraction**



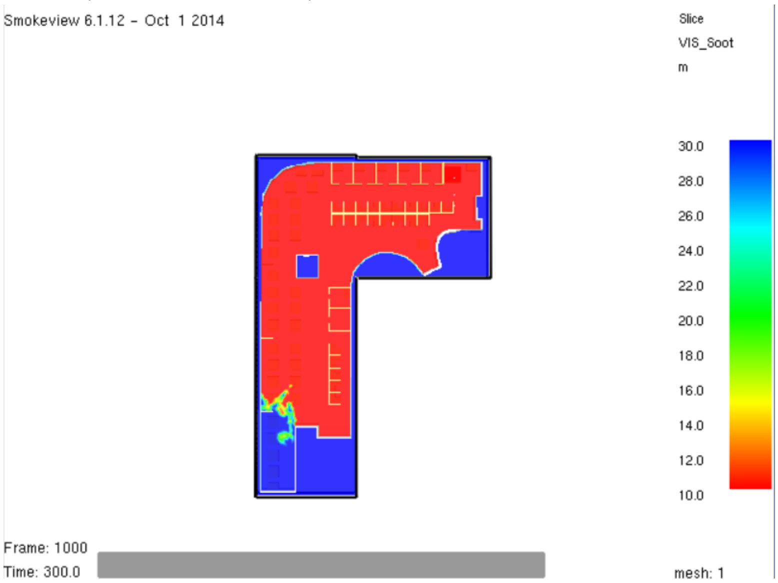
Zone 3, fire not in room



Zone 3, fire in room



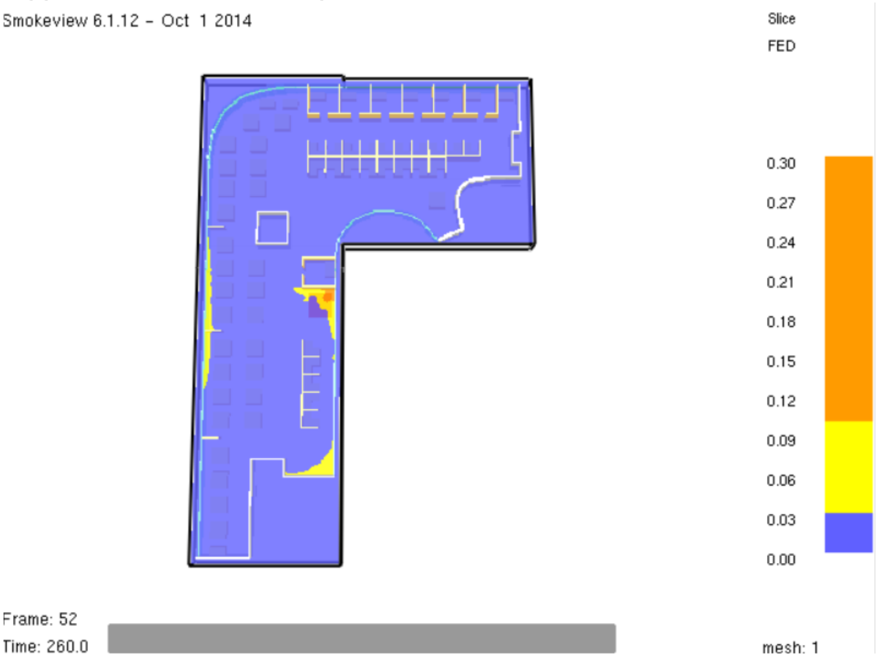
Zone 3, fire not in room, **with extraction**



RSET		ASET	
t_{det}	154s		FED_{co}<0.3
t_{alarm}	30s	Zone 1, fire not in room, with sprinklers	+400s > 260s
$t_{pre-movement}$	30s	Zone 2, fire not in room, with sprinklers	+400s > 260s
$t_{movement}$	46s	Zone 3, fire not in room, with sprinklers	+400s > 260s
TOTAL RSET	260s		

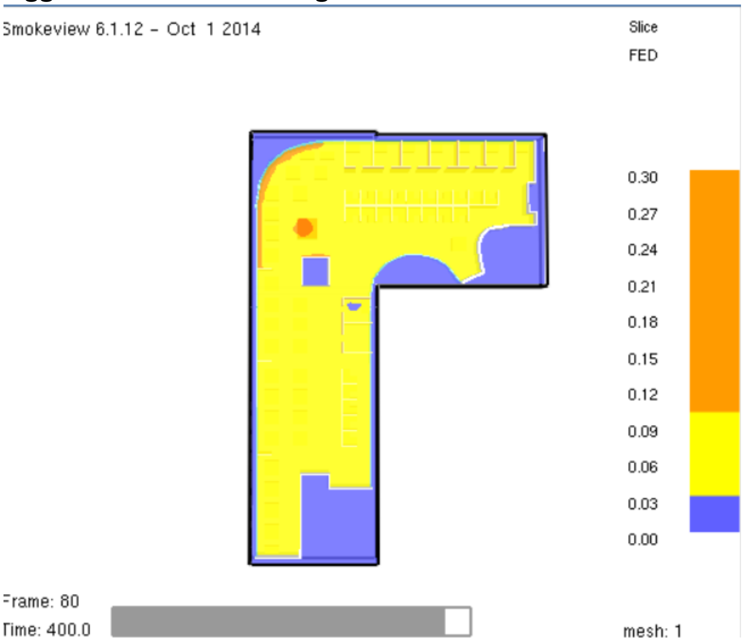
Zone 1, fire not in room, with sprinklers

A slice file is presented at 2m height of FED at 260 seconds. Only at certain regions an FED bigger than 0.3 is starting to show.

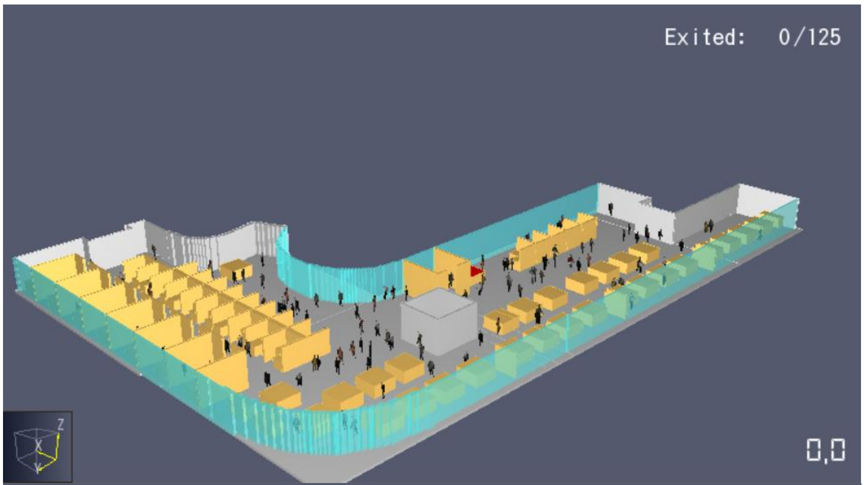


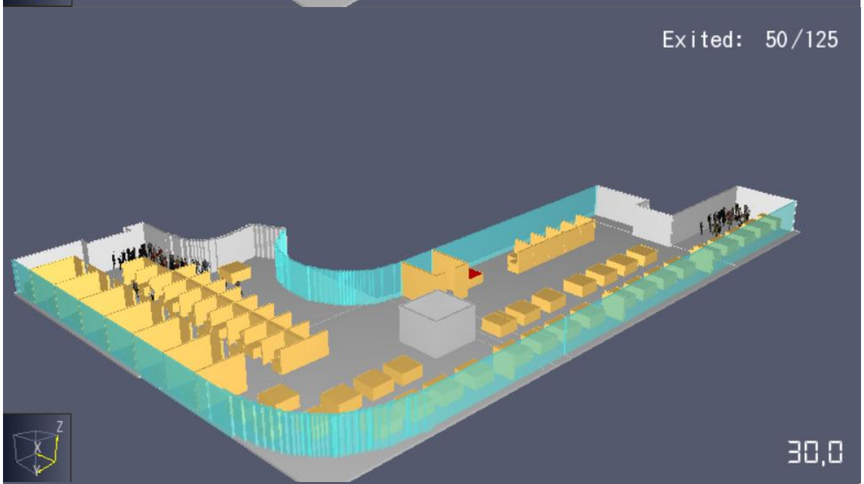
Zone 2, fire not in room, with sprinklers

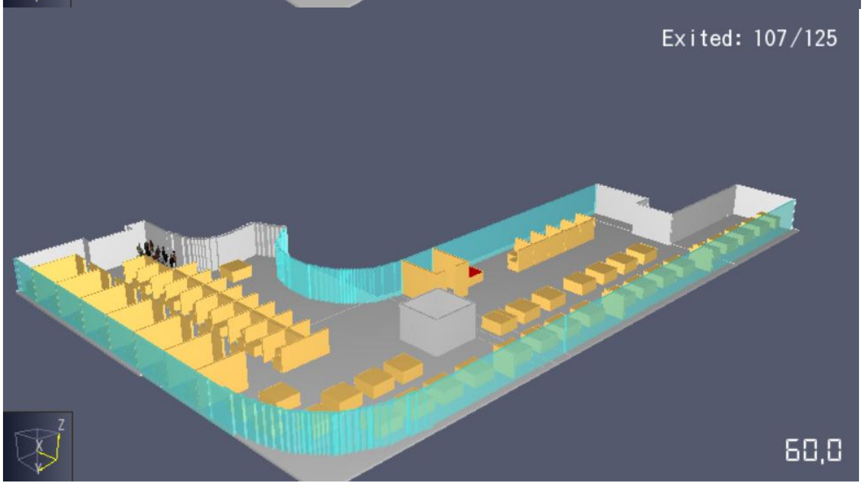
A slice file is presented at 2m height of FED at 400 seconds. Only at certain regions an FED bigger than 0.3 is starting to show.



Pathfinder screen shots







Appendix 6: Sweden

History legislation

The last full prescriptive legislation in Sweden was made mandatory in 1988 [55]. This included details for standard fire safety problems and simple buildings. There were no engineering calculations or technical systems that where recommended. This is called the standard method. This designing method was in 2000 still used in majority of the applications [56].

In 1994 [34], the regulations changed from prescriptive to function based design in Sweden. The reasons for this change of regulations by the government are summarised by Lundin [57]:

- European union harmonisation: in 1994 the European Economic Area agreement came into effect. The main objective was to achieve a technical harmonisation, e.g. REI values.
- Scientific grounds: the Swedish Parliament wanted a more scientific based regulation than a more rule of thumb based one.
- Deregulations: there was a general demand for deregulation by the public administration to create a higher efficiency.
- Simplification of regulations: It was both demand of the government and the industry to simplify complex regulations.
- Cleared division of responsibilities: It was aimed to make less ambiguous who was responsible, e.g. the owner and/or builder is responsible for following the regulations.
- Local government: If local governments would get more autonomy, there were a number of benefits expected, i.e. flexibility in construction process.
- Flexibility quality and freedom of choice: there was a feeling that the prescriptive regulations where limiting innovation.
- Reduction of cost: The construction cost where increasing more and more the last ten years before the 1994 regulations. It was hoped that the performance based method would lead to savings in costs.

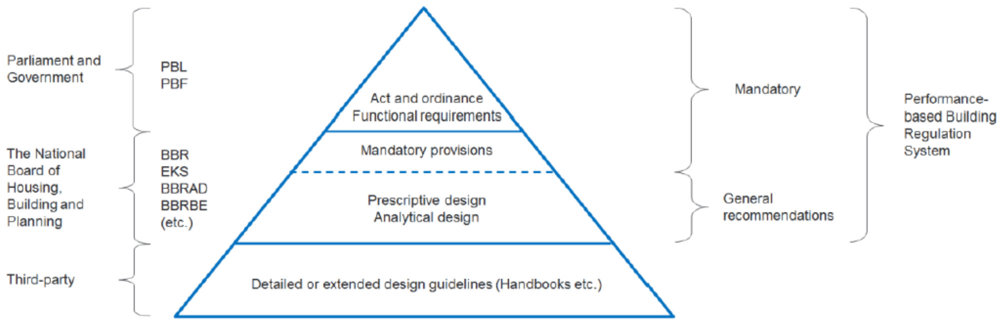
Revision of 1994 regulations started in 2006. A pre-study [7] was issued by Boverket, this is the Swedish National Board of Housing, Building and Planning. The objective of this pre-study was to make new regulations that comply with the Planning and Building Act (PBL) [36] and the Planning and Building Ordinance (PBF) [37].

The result of study had a big impact. The performance based fire regulations changes and acceptable level of safety was now explicit defined in the new regulations of 2012 [38].

The planning and building ordinance [37] includes 5 points based on the European construction products regulations (CPR, 2011):

1. The load bearing capacity of the construction can be assumed for a specific period of time;
2. The generation and spread of fire and smoke within the construction is limited;
3. The spread of fire to neighbouring construction works is limited;
4. People in the construction on fire can leave it or be rescued by other means;
5. The safety of fire and rescue service personnel is taken into consideration.

Point 1 in the above mentioned is regulated in Sweden in EKS [58]. Point 2 to 5 in the above mentioned is regulated within the Building Regulation (BBR) section 5 [38]. Compliance with the BBR can be achieved by either using the prescriptive design or by doing an Analytical Design (performance based). The structure of the Swedish regulatory system concerning fire safety can be found in the figure below.



Structure of the Swedish regulatory system from SPFE 2014 Gold Coast, Fire Safety Design of a Building with Interconnected Spaces - The Swedish case study [63]

Guidance in for the performance based design method is made available by Boverket through general recommendations with document name BBRAD [9]. This document for the

Analytical Design is already in its third edition, but had only few adaption's since the introduction in 2012.

Development of Performance Based Design framework

After the introduction of function based design in 1994 there was no clear guidance in performance based Engineering. An impact assessment [59] was made based on the recommendations of the pre-study [7] that had the goal of making a new performance based regulatory framework. The main objective of the pre-study was to make unambiguous levels of performance and goals. The pre-study showed there was a big uncertainly in acceptable level of safety. Furthermore it was also concluded that the current fire regulations were not sufficient quantifiable and therefore resulted in a complicated verification process. The pre-study indentified 3 sources for these problems:

- No national guidance for fire safety engineering.
- No guidance from legal system.
- Function based regulations with few performance levels or acceptable solutions.

A framework was developed in 2012, known as BBRAD that is now in its 3rd edition [9]. The purpose of that framework is to give specific guidance for designs to achieve an acceptable level of safety. This performance based design framework is generally applicable and can be used in other countries as well [8]. The global structure of the framework is based on the Nordic model made by the Nordic Committee on Building regulations [60] and the Inter-jurisdiction Regulatory Collaboration Committee[52]. The 5 main goals or functional requirements are derived from the European construction products regulations [61]. The purpose of the individual requirements is to give a robust fire safety regulations framework.

The operative requirements describe per sub-system what the function should be. These legally binding requirements allow different paths of achieving the goal: a prescriptive or performance based design solution can be used. A prescriptive or deemed-to-satisfy solution is always provided, but quantitative criteria is not always available. The goals and objectives per building and occupancy class are related to the associated risks based on the IRCC model. Performance groups are created to make this classification so an adequate protection level can be provided for different building and occupancies (e.g. hospitals versus regular office buildings).

There are two ways of designing that can be chosen to achieve an acceptable level of safety:

- Acceptable Solutions: This is the prescriptive and most common solution used to achieve compliance with the operative requirements [8]. This solution gives an indirect level of safety, which is important when designing without explicit quantitative performance criteria.
- Analytical Design: This is the performance based design method, used when the acceptable solutions is not possible or desired for the particular case. The PBD methods is seldom used to design an entire building, but is more frequently applied to deviate only partly from the prescriptive design[8].

An analytical design consists of 4 distinct steps:

1. Risk or hazard identification: First the circumstances must investigated of in which the performance based design will be performed. It is imperative to identify the specific risks directly related to the case as input for further analysis. The identified objectives can then be analysed in the verification process as suggested by Lundin [57]. The identification process can also point out which verification method should be used as well as the need for a robustness assessment.
2. Verification process: There are three different verification methods depending on how much is deviated from the acceptable solution:
    a. Qualitative Assessment: This method is only for minor deviations from prescriptive design. It can be a efficient way to achieve compliance using conservative assumptions for fairly standard buildings with some unique features.
    b. Scenario Analysis (deterministic): This is a performance based design type methodology provided with prescribed quantified input and required scenarios. The scenarios are chosen similar to the recommendations given by NFPA [27]. The input values are mainly chosen based on previous publications by Boverket or international recognised sources. An evaluation for safe egress can be performed using ASET- RSET calculation.

c. Quantitative Risk Assessment (QRA): There are general recommendations on how to perform a QRA (probabilistic). But the probabilistic criteria are not included, only the guidelines are given. An individual risk or societal risk analysis must be performed for the project or some type of probability of fire and smoke spread must be analysed.

3. It is the responsibility of the designer to review of verification
4. Documentation of verification are also required.

Appendix 7: Sprinkler activation

A fast growing fire from the Swedish legislation is simulated in a room with dimensions 10m x10m x 2.5m with an air inlet of 10 cm on the bottom to prevent the fire of becoming under-ventilated. The fire is placed in the middle of the room and the sprinkler right above it.

input data:

Area room	100 m^2
Height room	2.5 m
Area fire	1 m^2

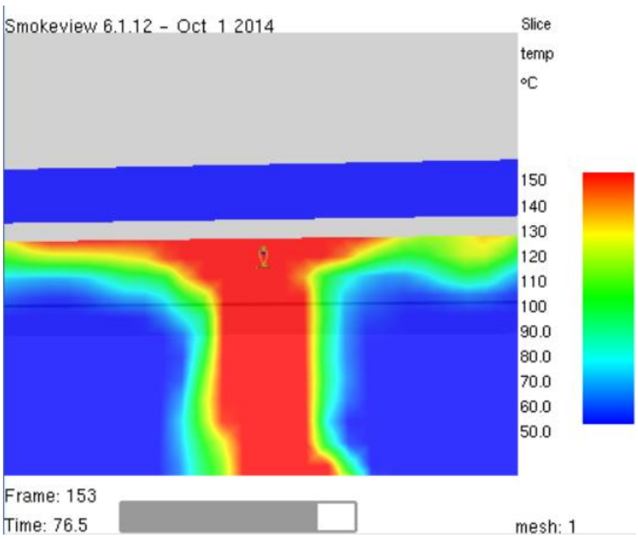
from BBRAD, Swedisch PBD framework: the fire

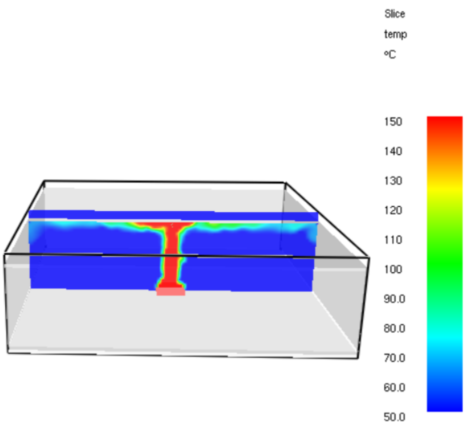
HRR	$0.047 * t^2$
Ysoot	0.10
Yco	0.10

From C/VM2, New Zealand PBD framework: standard response sprinkler

RTI	$135\sqrt{m\ s}$
C	$0.85\sqrt{m\ s}$
T_{act}	68°C

The sprinkler activates after 76.5 seconds or when the fire is at 275 kW. For the robustness scenario still a 2MW should have been used here which is a lot bigger then this fire when sprinkler activates in scenario 1.





Fds inputfile

```
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&TIME T_END=500/
&MISC SUPPRESSION=.FALSE., TMPA=20, RADIATION=.TRUE./
&RADI RADIATIVE_FRACTION=0.35/
&MATL ID          = 'CONCRETE'
    FYI         = 'Concrete'
    SPECIFIC_HEAT = 0.84
    DENSITY      = 2300
    CONDUCTIVITY  = 1.4
    EMISSIVITY   = 0.94/
&SURF ID                 = 'CONCRETE_WALL'
    ADIABATIC                          =.FALSE./
&SURF ID                 = 'CONCRETE_WALL_A'
    ADIABATIC                          =.TRUE./
&SURF       ID                                          ='BURNER'
            HRRPUA                                      = 10000
            ADIABATIC               =.TRUE.
            BACKING                                     ='INSULATED'
            TAU_Q                                       = -461/ tau_q is time until max HRR, neg for t²
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&REAC       FUEL                                        = 'PROPANE'
            HEAT_OF_COMBUSTION                          = 20000
            C                                           =1.19
            H                                           =4.79
            O                                           =1.0
            SOOT_YIELD                                  = 0.1
            CO_YIELD                        = 0.04/
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            MASS_EXTINCTION_COEFFICIENT=8700./
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&OBST XB=0,10,0,0,0.2,2.7, COLOR='GRAY 80', SURF_ID='CONCRETE_WALL',TRANSPARENCY=0.5/ wall room 1
&OBST XB=0,0,0,10,0.2,2.7, COLOR='GRAY 80', SURF_ID='CONCRETE_WALL'/ wall room 1
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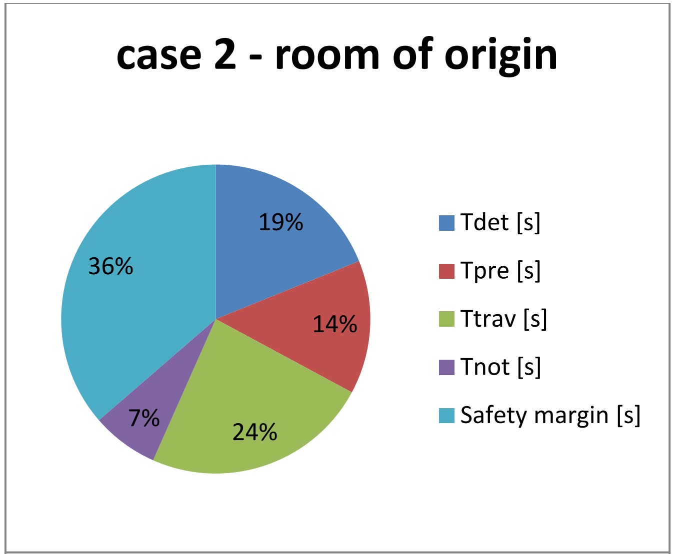
            VAPORIZATION_TEMPERATURE=100,
            MELTING_TEMPERATURE=0,
            HEAT_OF_VAPORIZATION=2259/
&PART ID='Water',
            SPEC_ID='Water_SPEC'
            DIAMETER=500
            DISTRIBUTION='ROSIN-RAMMLER'
            COLOR = 'BLUE'
            AGE=60/
&PROP ID = 'sprinkler'
            QUANTITY='SPRINKLER LINK TEMPERATURE'
            ACTIVATION_TEMPERATURE= 68
            RTI=135
            C_FACTOR=0.85
            PART_ID='Water'
            FLOW_RATE=1
            PARTICLE_VELOCITY=5.0/
&DEVC ID='S2', PROP_ID='sprinkler', XYZ= 5,5,2.5/
&VENT MB='XMIN', SURF_ID='OPEN'  /
&VENT MB='XMAX', SURF_ID='OPEN'  /
&VENT MB='YMIN', SURF_ID='OPEN'  /
&VENT MB='YMAX', SURF_ID='OPEN'  /
&VENT MB='ZMIN', SURF_ID='OPEN'  /
&VENT MB='ZMAX', SURF_ID='OPEN'  /
&SLCF QUANTITY='TEMPERATURE', PBZ=2.5/
&SLCF QUANTITY='TEMPERATURE', PBY=5/
&TAIL /
```

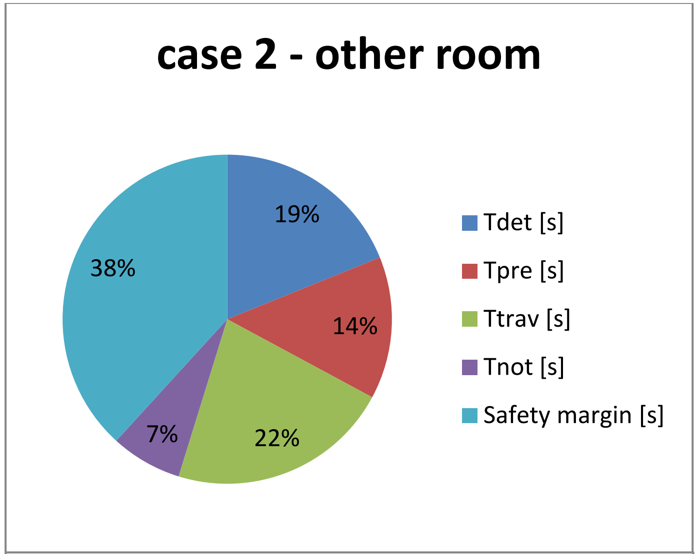
Appendix 8: Influence pre-movement times on RSET

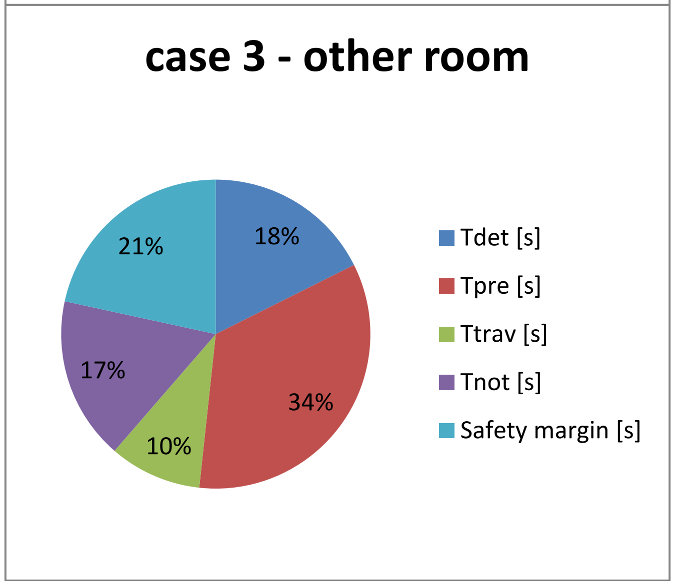
			Room of origin				Other room				Entire building			
			Framework 2008		C/VM2		Framework 2008		C/VM2		Framework 2008		C/VM2	
case 1	Tdet	[s]	34	20%	34	25%	117	26%	117	25%	117	22%	117	21%
	Tpre	[s]	120	72%	60	44%	300	68%	300	63%	300	56%	300	53%
	Ttrav	[s]	12	7%	12	9%	27	6%	27	6%	120	22%	120	21%
	Tnot	[s]			30	22%			30	6%			30	5%
	RSET	[s]	166	100%	136	100%	444	100%	474	100%	537	100%	567	100%
	ASET	[s]	31	visibiltiy	99	FED_CO	175	visibiltiy	N/A		N/A		N/A	
	Safety margin [s]		-135		-37		-269		N/A		N/A		N/A	
case 2	Tdet	[s]	81	22%	81	30%	81	23%	81	31%	81	16%	81	29%
	Tpre	[s]	180	50%	60	22%	180	51%	60	23%	360	73%	120	42%
	Ttrav	[s]	102	28%	102	37%	94	26%	94	35%	53	11%	53	19%
	Tnot	[s]			30	11%			30	11%			30	11%
	RSET	[s]	363	100%	273	100%	355	100%	265	100%	494	100%	284	100%
	ASET	[s]	207	visibiltiy	429	FED_CO	346	visibiltiy	429	FED_CO	N/A		N/A	
	Safety margin [s]		-156		156		-9		164		N/A		N/A	
case 3	Tdet	[s]	31	12%	31	23%	31	11%	31	22%	31	10%	31	20%
	Tpre	[s]	180	71%	30	23%	240	83%	60	43%	240	78%	60	38%
	Ttrav	[s]	42	17%	42	32%	17	6%	17	12%	35	11%	35	22%
	Tnot	[s]			30	23%			30	22%			30	19%
	RSET	[s]	253	100%	133	100%	288	100%	138	100%	306	100%	156	100%
	ASET	[s]	115	visibiltiy	115	visibiltiy	176	visibiltiy	176	visibiltiy	N/A		N/A	
	Safety margin [s]		-138		-18		-112		38		N/A		N/A	
case 4	Tdet	[s]	35	15%	35	29%	35	12%	35	23%	35	10%	35	18%
	Tpre	[s]	180	75%	30	25%	240	80%	60	40%	240	69%	60	30%
	Ttrav	[s]	24	10%	24	20%	25	8%	25	17%	75	21%	75	38%
	Tnot	[s]			30	25%			30	20%			30	15%

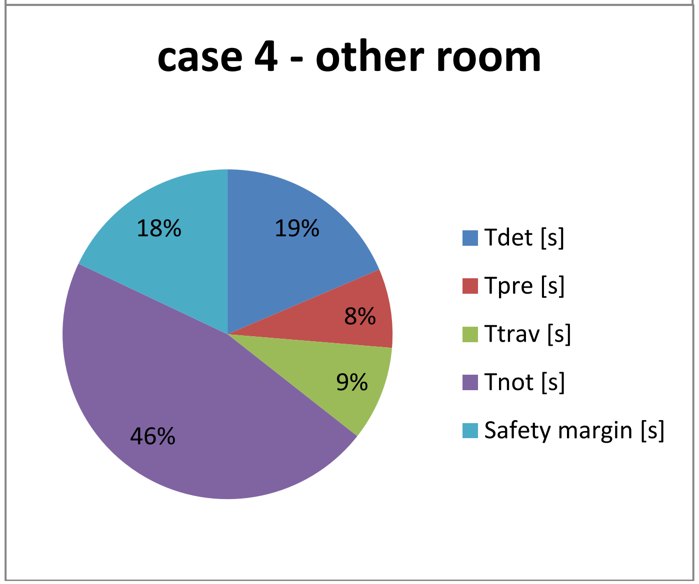
	RSET	[s]	239	100%	119	100%	300	100%	150	100%	350	100%	200	100%
	ASET	[s]	109	visibiltiy	109	visibiltiy	208	visibiltiy	208	visibiltiy	N/A		N/A	
	Safety margin [s]		-130		-10		-92		58		N/A		N/A	
case 6	Tdet	[s]	29	19%	29	23%	N/A		N/A		78	17%	78	11%
	Tpre	[s]	120	78%	60	48%	N/A		N/A		360	77%	600	81%
	Ttrav	[s]	5	3%	5	4%	N/A		N/A		30	6%	30	4%
	Tnot	[s]			30	24%	N/A		N/A				30	4%
	RSET	[s]	154	100%	124	100%	N/A		N/A		468	100%	738	100%
	ASET	[s]	22	visibiltiy	22	visibiltiy					N/A		N/A	
	Safety margin [s]		-132		-102						N/A		N/A	
case 9	Tdet	[s]	40	17%	40	28%	40	7%	40	10%	40	7%	40	10%
	Tpre	[s]	180	77%	60	42%	480	86%	300	73%	480	88%	300	75%
	Ttrav	[s]	14	6%	14	10%	40	7%	40	10%	28	5%	28	7%
	Tnot	[s]			30	21%			30	7%			30	8%
	RSET	[s]	234	100%	144	100%	560	100%	410	100%	548	100%	398	100%
	ASET	[s]	24	visibiltiy	83	FED_CO	147	visibiltiy	N/A		N/A		N/A	
	Safety margin [s]		-210		-61		-413							

RSET


case 2 - room of origin
19%
14%
24%
7%
36%
Tdet [s]
Tpre [s]
Ttrav [s]
Tnot [s]
Safety margin [s]


case 2 - other room
19%
14%
22%
7%
38%
Tdet [s]
Tpre [s]
Ttrav [s]
Tnot [s]
Safety margin [s]


case 3 - other room
18%
34%
10%
17%
21%
Tdet [s]
Tpre [s]
Ttrav [s]
Tnot [s]
Safety margin [s]


case 4 - other room
19%
8%
9%
46%
18%
Tdet [s]
Tpre [s]
Ttrav [s]
Tnot [s]
Safety margin [s]

Appendix 9: Survey

Questions

- Question 1 - Gender
  Suggested answers (not mandatory):
    - Man
    - Woman
- Question 2 - Age
  (not mandatory)
- Question 3 - Place where you are now. If you are at home, think of a relevant place such as shop, supermarket, office, school, etc.

  Fill in this place here:
- Question 4 - If you hear a fire alarm, do you believe it is burning?

  Suggested answers:
    - Yes, an alarm doesn't activate automatically.
    - No, it's probably an exercise.
    - Other:
- Question 5 - If nobody gives you further information about the alarm:
  Suggested answers:
    - I leave the building/room.
    - I look what the people around me do.
    - I wait until I get more information.
    - I ignore the alarm and keep on doing what I'm doing.
    - Other:
- Question 6 - If nobody gives you further information and the alarm continues, how long would you wait before leaving the building.
  Suggested answers:
    - Instantly leave the room/building
    - Wait 1/2 min.

- Wait 1 min.
- Wait 2 min.
- Wait 5 min.
- Wait 10 min.
- Wait 15 min.
- Ignore alarm.
- Other:

- Question 7 - If you see or smell smoke and you hear a fire alarm:

  Suggested answers:

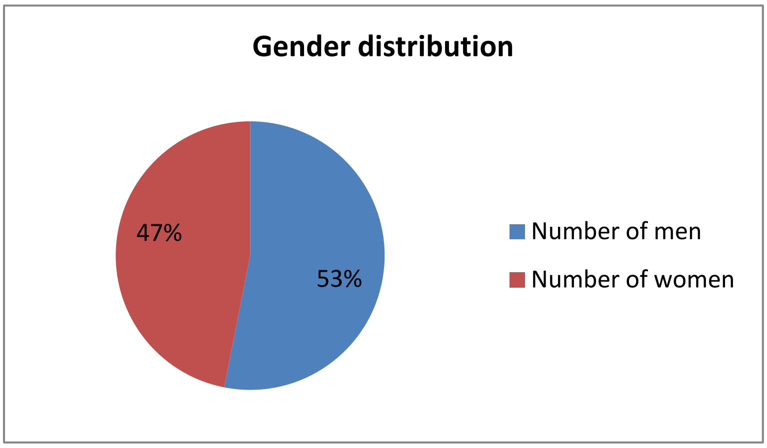
  - I leave the building/room.
  - I look what the people around me do.
  - I wait until I get more information.
  - I ignore the alarm and keep on doing what I'm doing.
  - Other:

Results

In total there were 194 unique participants to complete the survey. The results will be presented in pie-charts where relevant.

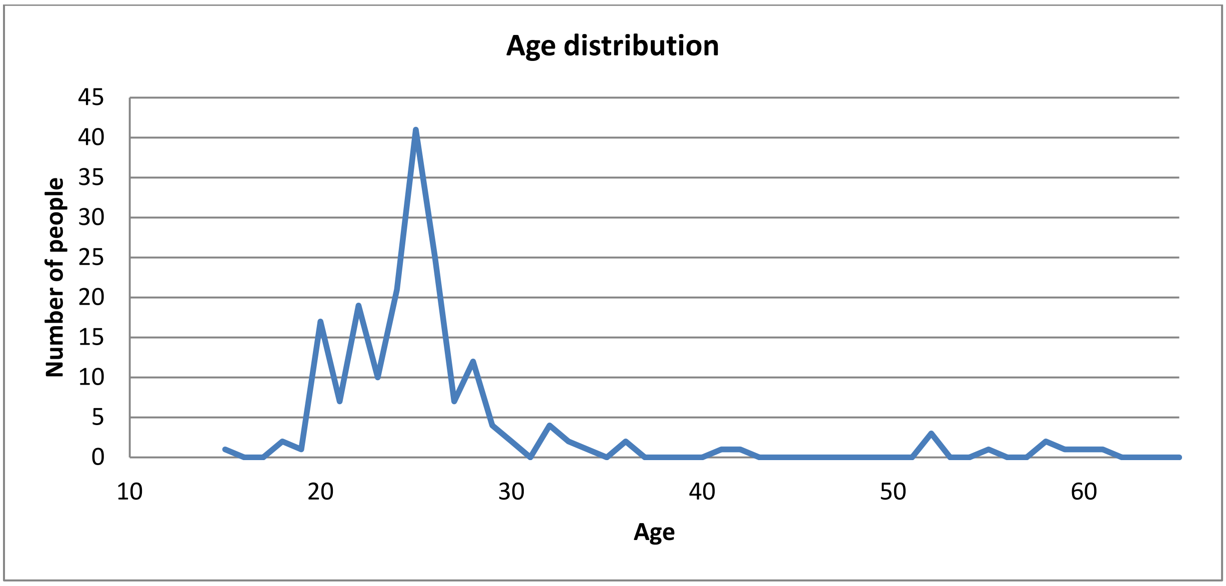
- Question 1

Slightly more men than women took part in the survey but the distribution quite even.



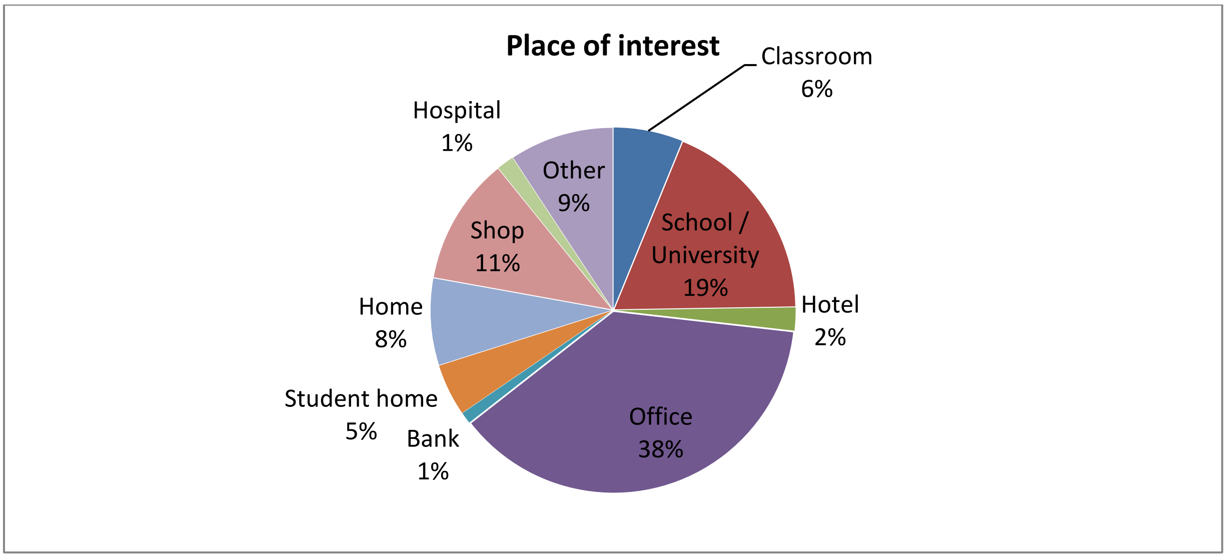
- Question 2

The age distribution of the participants shows in the graph a peak around the age of 25. It can be observed that 85% of the participants have an age between 20 and 30 years old.



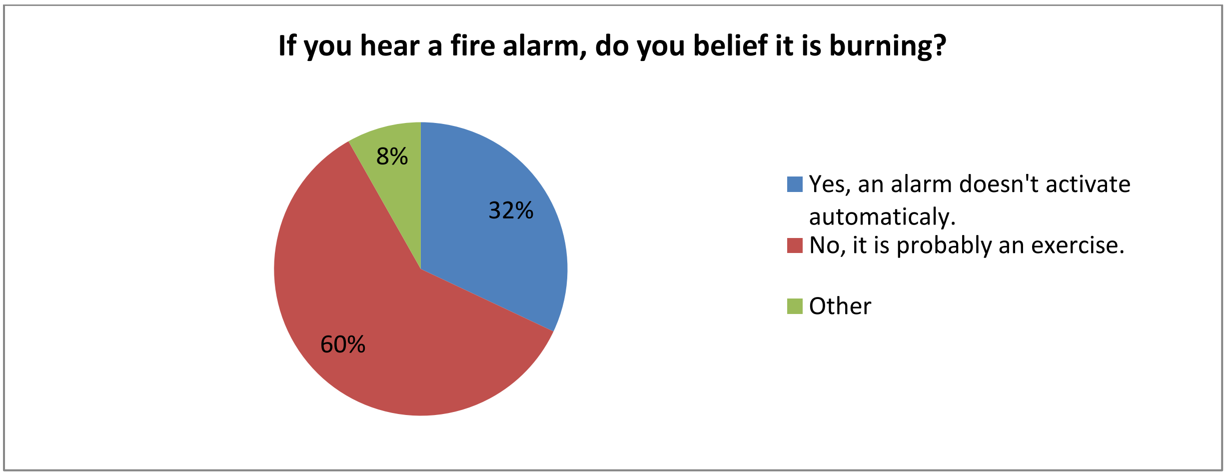
- Question 3

The third question asked to imagine a place to create a realistic atmosphere for the participant to continue the survey. A wide distribution of answers are giving with the biggest share in the office and school/university representing together 57% of the answers. Other answers such as home, student home, shop, hotel, etc. are other less frequently answered.



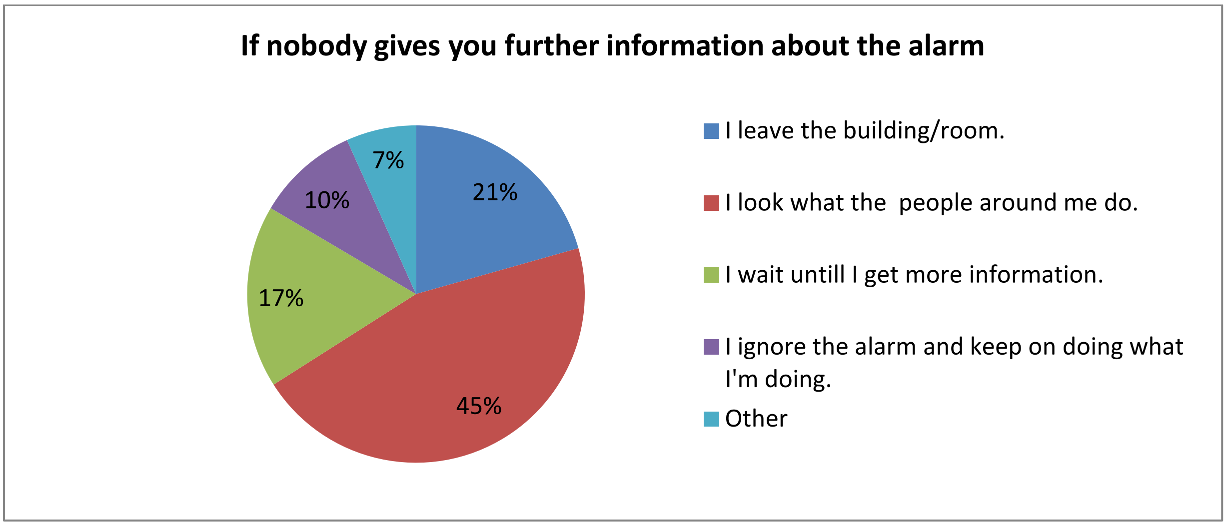
- Question 4

The results of question 4 show that only 32% of the people actually belief that a fire alarm is the result of a fire in the building. 60% of the people agrees with the statement that it is probably only an exercise. The majority in group marked as other thinks the alarm is the result of a technical or human error. None of the people in this group however beliefs that alarm is the result of a fire.



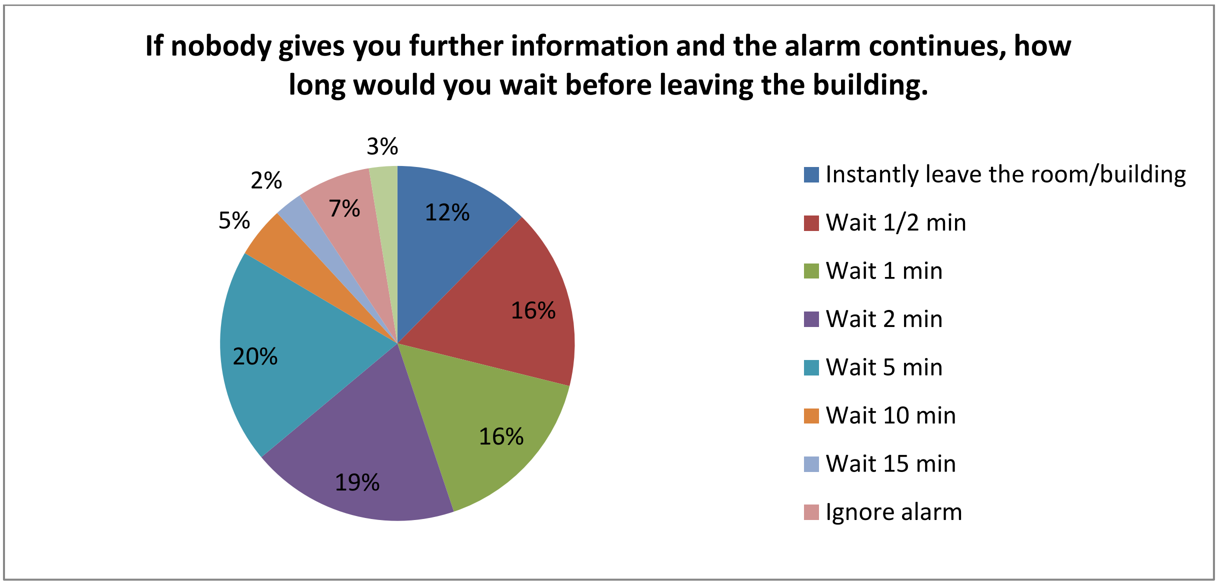
- Question 5

Only 21% of the people believe that they will evacuate the building if no further information is given about the fire alarm according to question 5. The majority of the people (45%) believe that they would be influenced by what the people around them do. A smaller group represented by 17% would wait to get more information before evacuating. In the group other (7%) they go investigate why there is an alarm. 10% of the people confirms that they would ignore the alarm and keep on doing what they are doing.



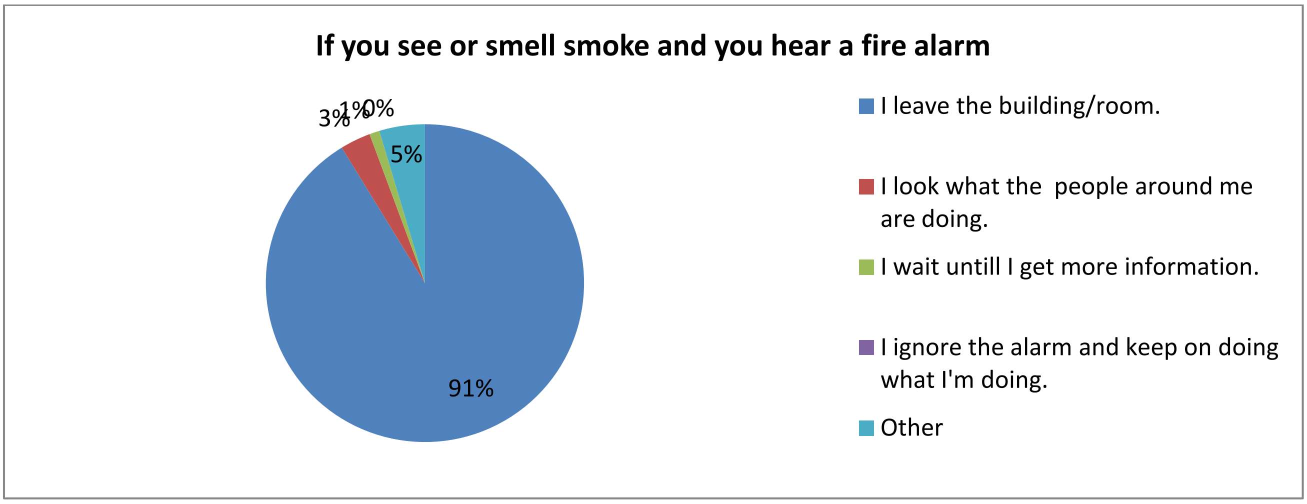
- Question 6

Question 6 tries to get an overview of how long the participants estimate that they would wait before starting to evacuate. 12% of the participants beliefs that they would instantly leave the building. 51 % of the participants represent the people that would leave the building within 5 minutes. The resulting 37% of the participants beliefs to wait longer than 10 minutes or not to leave the building at all.



- Question 7

The last question introduces a second cue on top of the fire alarm. 91 % of the participants believes to leave the building instantly. In the group other represented by 5% a frequent answer is to investigate the situation further.


If you see or smell smoke and you hear a fire alarm
3%
1%
0%
5%
91%
I leave the building/room.
I look what the people around me are doing.
I wait untill I get more information.
I ignore the alarm and keep on doing what I'm doing.
Other

Datum	Vraag 1	Vraag 2	Vraag 3	Vraag 4	Vraag 5	Vraag 6	Vraag 7
10/2/2015 om 15u 58m 40s	Vrouw	23	Op kot	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 15u 59m 46s	Vrouw	22	clublokaal campus schoonmeersen	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 00m 00s	Vrouw	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 03m 00s	Vrouw	26	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik vraag het na en indien het niet 'normaal' is verlaat ik het gebouw	2 minuten	Ik ga kijken wat de oorzaak van de rook is. Indien ik het zelf kan verhelpen doe ik dit. Indien ik zie dat het om een groot vuur gaat verlaat ik meteen het gebouw
10/2/2015 om 16u 05m 15s	Vrouw	33	thuis	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	10 minuten	Ik kijk wat de andere personen om mij heen doen
10/2/2015 om 16u 06m 48s	Man	26	toilet	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 08m 20s	Man	23	jeugdlokaal	Nee, het zal wel de zoveelste oefening zijn	Ik zoek uit waarom het alarm afgaat	Direct het gebouw verlaten	Ik zoek uit waar de rook geur vandaan komt
10/2/2015 om 16u 08m 50s	Man	24	school	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 09m 08s	Man	21	School	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 10m 12s	Man	24	kot	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 10m 58s	Man	32	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 13m 30s	Vrouw	25	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte

10/2/2015 om 16u 16m 33s	Man	29	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 19m 58s	Man	24	kantoor	Ik ga wel eens buiten kijken maar zal me niet haasten	Ik kijk wat de andere personen om mij heen doen	Laptop inpakken, jas aan en weg	Laptop inpakken, jas aan en direct weg
10/2/2015 om 16u 20m 32s	Man	29	werk	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 20m 43s	Vrouw	26	werkplaats	Ik zou eerder denken dat het een oefening of vals alarm is, maar hou steeds in het achterhoofd dat het wel degelijk een brand zou kunnen zijn.	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 23m 32s	Man	27	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 24m 04s	Man	25	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 26m 32s	Vrouw	24	thuis	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 26m 54s	Man	25	school	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 28m 59s	Man	18	school	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 34m 50s	Man	28	werk	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 38m 24s	Man	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 16u 39m 21s	Man	26	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte

10/2/2015 om 17u 05m 38s	Vrouw	24	Fitness	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 16m 08s	Vrouw	52	0	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 17m 58s	Man	28	in Bangkok, Thailand	Ja, een brandalarm gaat niet zomaar af	kijk of er brand is	10 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 31m 23s	Vrouw	26	werk	Probleem met het alarmsysteem	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 31m 45s	Vrouw	22	op kot	Iemand die aan het koken is	kijken vanwaar het signaal komt	Negeer alarm	Ik kijk wat de andere personen om mij heen doen
10/2/2015 om 17u 35m 19s	Vrouw	27	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 35m 41s	Vrouw	23	school	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 17u 41m 49s	Vrouw	41	bank	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 18u 02m 49s	Man	42	kantoor	Ja, een brandalarm gaat niet zomaar af	klein kantoor, ik check zelf of er brand is.	Negeer alarm	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 18u 12m 16s	Vrouw		hotel	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 18u 21m 36s	Vrouw	24	praktijkruimte	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 18u 35m 36s	Vrouw	25	winkel	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	10 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 18u 47m 29s	Vrouw	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 00m 34s	Vrouw	24	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte

10/2/2015 om 19u 03m 49s	Man	21	Winkel	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Negeer alarm	Ik kijk wat de andere personen om mij heen doen
10/2/2015 om 19u 05m 04s	Vrouw	26	supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 23m 06s	Man	26	Sportclub	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 23m 26s	Man	25	School	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 27m 10s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 34m 42s	Man	26	Werk	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 39m 53s	Vrouw	28	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 45m 01s	Man	24	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 19u 48m 59s	Man	24	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 04m 13s	Vrouw	20	supermarkt	Het hangt ervan af hoe serieus het personeel reageert en of er rook of andere signalen zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 14m 28s	Man	26	werk	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 15m 37s	Vrouw	26	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte

10/2/2015 om 20u 20m 25s	Man	26	supermarkt	Nee, het zal wel weer een vergissing zijn of het zal maar een klein brandje zijn dat ze zelf kunnen blussen	Ik negeer het alarm en doe verder waar ik bezig mee ben.	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 20m 50s	Man	25	Living	Ja, een brandalarm gaat niet zomaar af	op zoek gaan naar de oorzaak	op zoek gaan naar de oorzaak	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 34m 00s	Man	25	hotel	Ja, een brandalarm gaat niet zomaar af	Personen rondom mij verzamelen en naar buiten gaan.	1 minuut	Personen rondom mij verzamelen en naar buiten gaan.
10/2/2015 om 20u 37m 39s	Man	26	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 38m 02s	Man	24	School	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 45m 41s	Man	27	Keuken te Polen	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 49m 34s	Man	26	thuis	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 20u 53m 34s	Man	55	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Negeer alarm	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 00m 02s	Man	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik wacht of tot ik meer informatie krijg
10/2/2015 om 21u 05m 20s	Vrouw	25	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 13m 36s	Vrouw	25	Thuis	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 14m 36s	Man	25	School	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 17m 05s	Vrouw	22	Winkel	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	5 minuten	Ik kijk wat de andere personen om mij heen doen

10/2/2015 om 21u 21m 51s	Vrouw	22	kot	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 24m 17s	Vrouw	23	supermarkt	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 25m 57s	Vrouw	23	school	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 36m 05s	Man	22	Kot	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 51m 36s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 21u 53m 35s	Vrouw	21	school	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 07m 55s	Man	26	thuis	Nee, het zal wel de zoveelste oefening zijn	gaan kijken als er iets scheelt	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 23m 32s	Man	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	15 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 24m 46s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 26m 19s	Man	25	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 37m 11s	Vrouw	25	Kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	10 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 38m 55s	Man	24	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 39m 44s	Man	23	Hotel	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 22u 41m 50s	Vrouw	24	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte

10/2/2015 om 22u 43m 20s	Man	26	bibliotheek	geen oefening, maar geen brand (techniche fout/menselijke fout)	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik kijk of ik anderen kan waarschuwen in het gebouw en bel 112
10/2/2015 om 23u 08m 59s	Man		winkel	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 23u 29m 32s	Man	26	THUIS	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte
10/2/2015 om 23u 49m 15s	Man	26	Kantoren	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	2 minuten	Probeer bron te vinden en doven
10/2/2015 om 23u 51m 33s	Man	25	winkel	het zal wel per ongeluk afgaan	Ik negeer het alarm en doe verder waar ik bezig mee ben.	ik zou de winkel eventueel wel verlaten uit ergernis na verloop van tijd indien het alarm blijft afgaan en er geen info volgt	Ik kijk wat de andere personen om mij heen doen
11/2/2015 om 0u 11m 17s	Man	25	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Negeer alarm	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 0u 28m 22s	Vrouw	24	Werk	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 8u 04m 54s	Man	30	Slaapkamer	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 8u 58m 03s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 9u 09m 05s	Vrouw		0	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik wacht of tot ik meer informatie krijg
11/2/2015 om 9u 18m 57s	Man	29	Kantoor	Wat nu weer!	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte

11/2/2015 om 9u 32m 56s	Man	1265 (grapje 28)	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 9u 33m 16s	Man	18	Auditorium quetelet tweekerkstraat	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Direct het gebouw verlaten	Ik kijk wat de andere personen om mij heen doen
11/2/2015 om 9u 40m 02s	Man	28	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 9u 56m 24s	Vrouw	22	school	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 9u 59m 50s	Vrouw	26	Kot	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	15 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 10u 28m 11s	Vrouw	25	werk	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	15 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 10u 41m 34s	Vrouw	33	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 10u 47m 42s	Man	52	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 11u 10m 21s	Man	24	thuis	Ja, een brandalarm gaat niet zomaar af	Ik informeer me	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 11u 53m 25s	Man	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 11u 57m 55s	Vrouw	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 12u 24m 45s	Vrouw	22	thuis	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	15 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 12u 40m 10s	Man	58	supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte

11/2/2015 om 12u 52m 04s	Vrouw	23	unief	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 13u 21m 09s	Man	25	kantoor	defect	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 13u 34m 20s	Vrouw	19	op kot	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 13u 55m 07s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 14u 00m 38s	Man	26	thuis	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	Hoe luider/opvallender het alarm, des te sneller ben ik buiten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 14u 12m 28s	Vrouw	29	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 14u 15m 42s	Man	27	kantoor (werk)	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	ik bekijk of er wel echt brand is vooraleer ik alarm acitveer
11/2/2015 om 14u 19m 32s	Man	26	school	vals alarm	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 15u 09m 41s	Vrouw	34	Kantoor	Kortsluiting in atelier, draaiende vaatwas openen onder melder	Ik informeer zelf.	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 15u 28m 48s	Vrouw	58	hotel	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 15u 29m 03s	Vrouw	36	school	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 00m 31s	Man	24	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 05m 17s	Man	24	school	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte

11/2/2015 om 16u 10m 24s	Man	26	werk	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 10m 31s	Vrouw	61	thuis	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 32m 38s	Man	28	kantoor	Even navragen bij de collega's wat zij denken	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 36m 39s	Vrouw	22	aula	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 16u 59m 42s	Man	20	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 17u 30m 52s	Man	32	Werk	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 18u 43m 44s	Vrouw	60 jaar	supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 18u 54m 36s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 19u 39m 51s	Man	24	Trein brugge-torhout	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 19u 46m 03s	Man	25	Voetbalkantine	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 19u 57m 03s	Vrouw	25	werk	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 20u 06m 04s	Man	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Negeer alarm	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 20u 15m 45s	Man	28	kantoor	Ja, een brandalarm gaat niet zomaar af	ik onderzoek het zelf!	zie bovenstaand antwoord.	ik blus de brand!
11/2/2015 om 21u 04m 29s	Vrouw	24	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1/2 minuut	Ik verlaat het gebouw/ de ruimte

11/2/2015 om 21u 33m 49s	Vrouw	27	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 22u 08m 41s	Vrouw	26	winkel	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	2 minuten	ik verlaat het gebouw en probeer ander mensen aan te sporen hetzelfde te doen
11/2/2015 om 23u 25m 14s	Vrouw	23	kantoor	we zien wel	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
11/2/2015 om 23u 45m 43s	Vrouw	23	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 0u 22m 44s	Man	32	Thuis	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 0u 38m 02s	Man	36	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	2 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 9u 13m 03s	Vrouw	26	Kantoor	Technisch defect, storing	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 11u 41m 27s	Vrouw	22	school	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 12u 15m 14s	Vrouw	32	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 12u 27m 12s	Vrouw	25	bureau	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 13u 14m 19s	Vrouw	25	Zeepreventoriu m	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 14u 01m 03s	Man	28	Kantoor	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 14u 56m 52s	Vrouw		Basel, Zwitserland	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 15u 40m 04s	Vrouw	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte

12/2/2015 om 15u 59m 32s	Vrouw	20	Auditorium	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 16u 20m 01s	Vrouw	24	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	10 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 17u 38m 25s	Man	28	Thuis	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 17u 48m 49s	Man	28	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 17u 52m 21s	Vrouw	25	ziekenhuis	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 18u 08m 43s	Man	30	kantoor	Ja, een brandalarm gaat niet zomaar af	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Negeer alarm	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 18u 12m 38s	Vrouw	20	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 18u 20m 53s	Vrouw	20	School	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 18u 37m 03s	Vrouw	26	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 18u 42m 54s	Man	20	Auditorium	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 19u 09m 09s	Man	21	School	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	10 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 19u 12m 59s	Man	24	Studio in Wales	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 19u 56m 22s	Vrouw	20	school	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 20u 15m 22s	Vrouw	25	Kantoor	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte

12/2/2015 om 21u 23m 35s	Man	20	aditorium	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 21u 48m 21s	Man	20	School	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	1/2 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 23u 23m 00s	Man	20	Supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	1 minuut	Ik verlaat het gebouw/ de ruimte
12/2/2015 om 23u 23m 50s	Vrouw	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 7u 26m 02s	Vrouw	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	10 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 7u 35m 28s	Vrouw	25	Trein	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 8u 04m 42s	Vrouw		school	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	2 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 11u 39m 59s	Vrouw	25	praktijk	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 13u 29m 03s	Man	20	school	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 14u 25m 13s	Vrouw	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 14u 25m 50s	Man	21	op universiteit	Ja, een brandalarm gaat niet zomaar af	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 18u 07m 02s	Vrouw	22	Sporthal	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	15 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 18u 10m 56s	Man	15	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
13/2/2015 om 19u 13m 06s	Vrouw	22	Op kot	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	10 minuten	Ik verlaat het gebouw/ de ruimte

13/2/2015 om 23u 27m 44s	Man	22	winkel	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 3u 06m 55s	Man	20	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 9u 25m 12s	Vrouw	24	ziekenhuis	Ja, een brandalarm gaat niet zomaar af	Ik wacht of tot ik meer informatie krijg	2 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 10u 11m 00s	Vrouw	20	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 10u 48m 44s	Vrouw	25	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 10u 57m 07s	Vrouw	21	auditorium	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	2 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 12u 03m 59s	Vrouw	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 12u 14m 38s	Man	20	school	eerst niet maar ik check het toch voor de zekerheid eens	ik zoek iemand die meer informatie heeft	1 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 12u 28m 50s	Vrouw	21	Unief	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 14u 23m 49s	Vrouw	22	school	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	10 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 15u 09m 25s	Man	27	Supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 15u 09m 25s	Man	27	Supermarkt	Ja, een brandalarm gaat niet zomaar af	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 15u 21m 59s	Man	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 17u 11m 23s	Man	20	universiteit	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte

14/2/2015 om 17u 24m 11s	Man	28	Auto	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat er aan de hand is	5 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 17u 48m 00s	Man	23	school	Nee, het zal wel de zoveelste oefening zijn	Ik wacht of tot ik meer informatie krijg	5 minuten	Ik verlaat het gebouw/ de ruimte
14/2/2015 om 23u 16m 43s	Man	59	Ziekenhuis	Nee, het zal wel de zoveelste oefening zijn	Ik negeer het alarm en doe verder waar ik bezig mee ben.	Negeer alarm	Ik verlaat het gebouw/ de ruimte
15/2/2015 om 14u 36m 39s	Vrouw	25	Kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
15/2/2015 om 16u 31m 40s	Vrouw	20	universiteit	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1/2 minuut	Ik verlaat het gebouw/ de ruimte
15/2/2015 om 16u 37m 49s	Vrouw	20	auditorium	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	5 minuten	Ik verlaat het gebouw/ de ruimte
15/2/2015 om 16u 59m 36s	Vrouw	26	Bank	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
15/2/2015 om 17u 12m 08s	Man	22	School	Nee, het zal wel de zoveelste oefening zijn	Ik kijk wat de andere personen om mij heen doen	1 minuut	Ik verlaat het gebouw/ de ruimte
16/2/2015 om 23u 15m 26s	Man	28	kantoor	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte
17/2/2015 om 18u 55m 31s	Vrouw	52	School	Nee, het zal wel de zoveelste oefening zijn	Ik verlaat het gebouw/ de ruimte	Direct het gebouw verlaten	Ik verlaat het gebouw/ de ruimte

Appendix 10: C/VM2 - Horizontal fire spread

The fifth scenario considers fire spread to adjacent buildings. The received radiation at a relevant boundary of the property should not exceed 30 kW/m². Moreover should the radiation not exceed 16 kW/m² at a distance 1 m beyond the boundary (Clause C3.6 from NZBC). External walls closer than 1m to the boundary need to be constructed out of non-combustible or limited combustible materials (Clause C3.7 from NZBC).

FLED = 800MJ/m² radiation 103 kW/m²

conservative assumption size of the unprotected area: 4 m x 20 m

(not sprinklered: width of the enclosing rectangle: smaller than 20m)

$$Q^{"}_{rad} = E * \phi$$

With $E = 103\ kW/m^2$ the amount of energy emitted per unit area [kW/m²]

ϕ the configuration factor [-] [62]

$Q^{"}_{rad} = 30\ kW/m^2$ the radiation received [kW/m²]

Limitation 1: Calculation of how far the building must be away from the boundary based on maximum 30 kW/m² on the boundary.

$$\phi = \frac{30}{103} = 0.29$$
$$\phi = \phi_A + \phi_B + \phi_C + \phi_D = 0.29$$
$$\phi_A = \phi_B = \phi_C = \phi_D = 0.07$$
$$S = {}^{L_1}/_{L_2} = {}^{2}/_{10} = 0.2$$
$$\alpha = \frac{L_1 * L_2}{D^2} = \frac{2 * 10}{D^2} = 0.5$$
$$D = \sqrt{\frac{20}{0.5}} = 6.3m$$

Limitation 2: Calculation of how far the building must be away from the boundary based on maximum 16 kW/m² on the boundary

$$\phi = \frac{16}{103} = 0.16$$
$$\phi = \phi_A + \phi_B + \phi_C + \phi_D = 0.16$$
$$\phi_A = \phi_B = \phi_C = \phi_D = 0.04$$

$$S = {}^{L_1}/_{L_2} = {}^{2}/_{10} = 0.2$$

$$\alpha = \frac{L_1 * L_2}{D^2} = \frac{2 * 10}{D^2} = 0.2$$

$$D = \sqrt{\frac{20}{0.2}} = 10m$$

The limiting distance is 9m from the boundary.

The design complies with the design scenario