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FIRE EVACUATION ANALYSIS OF THE MANCHESTER WOOLWORTHS FIRE USING NETWORK MODELLING

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Abstract. *Fire engineers are able to gather and learn a significant amount of information from previous incidents. Large fires, even though they can lead to tragic loss of life, provide insight into fire development and evacuee response. Simulations based upon a real-life scenario can be a useful tool when trying to understand how the fire affected the behaviour of the occupants and the choices they made. This research adopts a probabilistic network modelling methodology for building evacuation based on a real fire event. The aim of this research is to recreate a fire emergency evacuation from the Woolworths department store, applying the EvacuatioNZ egress model. The predominant research objective is to benchmark the capabilities of EvacuatioNZ and assist in its continuous development by evaluation of possible model limitations. The EvacuatioNZ software has been selected as a tool for this research, because it enables the user to consider random choices regarding exiting strategies to simulate probabilistic scenarios with a number of uncertainties.*

1 INTRODUCTION

The fire incident occurred in the Woolworths store located near Piccadilly Gardens in the centre of Manchester on Tuesday 8th of May 1979. Before the fire was extinguished, 10 people lost their lives, nine shoppers and one staff member. All fatalities occurred on the second floor of the eight storey building. 53 people were taken to hospital for treatment, including 6 firemen, 32 people were rescued by the fire brigade via doors, windows and the roof [1].

1.1 Basic Features of the Building

The store was built in 1929 and comprised eight floors, including a basement and sub-basement [2]. The store was approximately 42 m x 35 m in plan. The sub-basement was unoccupied and used for fuel storage and housed the emergency lighting generator. The basement, ground, first and second floors were used as retail floors and the second floor also contained a restaurant, as shown in Figure 1. The third floor contained staff facilities, and the kitchen for the public restaurant on the second floor. The fourth and fifth floors were used as storage areas and also contained a mechanical plantroom.

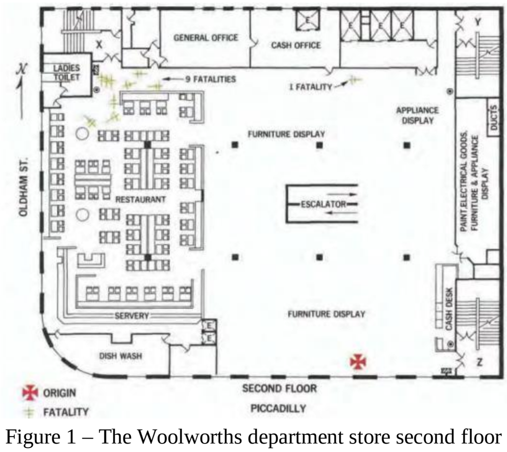

Figure 1 – The Woolworths department store second floor layout [1]

The fire started between approximately 13:20 and 13:25 [2] in the second floor furnishing department storage area, where vertically stacked furniture was wrapped in a protective covering of polyethylene. The cause of fire was a damaged electrical cable, which ignited furniture stacked in front of it. The fire was not noticed until the flames were seen above the furniture.

There were approximately 500 people in the building, 69 of which were staff members. The restaurant could seat 208 people, but at the time of fire, there were between 70 to 100 people in that area [2]. According to Sime [3], the second and third floor were heavily populated by staff and public.

Enclosed stairways served all floors and were situated at three corners of the building, with final exits directly to the outside at ground level [1]. The stairways had intermediate doors that were used to prevent public access to the third and fourth floors of the building. These doors were locked from the inside. Open escalators ran from basement area to the second floor.

1.2 Fire Development and Rescue

A painter working on a ladder noticed flames above the furniture [2]. The flames were not reaching the ceiling, were about 1.2 m to 1.5 m wide, and were not accompanied by smoke. After notifying management and people in the restaurant, the painter went back across the floor to move his spray equipment away from the fire, by which time flames had extended and smoke had begun to develop. In the painters' words "It was like a black layer forming across the ceiling". At this time the store manager tried to extinguish the fire with a hose reel, but this attack was abandoned as conditions quickly grew more severe. By that time the flames had reached the head of the escalator.

The building was provided with manual call points on each floor [2]. Woolworths staff were poorly trained and did not immediately raise the alarm. Their first reaction was to try to extinguish the fire. The fire alarm was eventually operated by a security guard on the first floor, and the sounders operated for 3 - 4 min. The majority of the occupants escaped during the sounding of the alarm. Eye witnesses said that the rapid spread of fire through the second floor trapped many staff and customers on that floor, and also staff on the upper levels who did not hear an alarm. When staff became aware of fire, they were unable to escape through the smoke. They remained in the office, from where they were rescued by the fire brigade personnel who cut bars on the office windows and helped them down to the ground level.

The fire brigade personnel arrived at the scene of the fire about 10 min after the fire started. Firefighters found an extensive fire involving the second floor with smoke coming from the front and side of the building at the second floor level. They could see people behind barred windows on the second, third and fourth floors, and people calling for help from the roof. At this time conditions in the stairways were as follows:

- The Oldham Street stairway X, refer Figure 1, was heavily smoke logged to the first floor level.
- The Piccadilly stairway Z, had smoke present but could still be used for escape.
- The back Piccadilly stairway Y had a similar amount of smoke to that found in stairway Z, but the door was fastened with a padlock and chain from inside. This stair could not be used until the fire brigade had cut the chain to open it.
- The second floor itself was impenetrable because of heat and smoke.

Six people were rescued by the Fire Brigade from second floor office windows at 13:35 [4]. By 13:40 firefighters needed breathing apparatus, due to intense heat and dense smoke [5]. By 13:45 all 26 people from the roof and windows were rescued.

1.3 Post Incident

An inquiry by the Fire Service [4] showed that the main reason for the high number of casualties was that the furniture made of polyurethane foam produced large amounts of toxic smoke. The smoke not only caused breathing problems, but also obscured exit signs. Investigations into the fire found that smoke on the second floor was so thick, that people could not find their way to the exits.

Woolworths disaster has become a focus of study for those interested in the behaviour of people in emergency situations, after research showed a number of customers (predominately in the public restaurant area) refused to leave despite the sounding of alarms, requests from staff, and even the smell and visibility of smoke; some even continued to queue at an abandoned checkout. The report suggested that people in the restaurant simply refused to leave because they had just paid for their meals, and wanted to make the most of their money [4].

2 METHODOLOGY

Computer modelling of a fire event and comparing actual incident to a model is an approach widely adopted in research strategies. Other researchers have modelled incidents, such as The Station Nightclub Fire [6], King's Cross Fire [7], World Trade Center Disaster [8]. This research uses the EvacuatioNZ evacuation egress software as a part of ongoing research at University of Canterbury. The predominant research objective was to benchmark the capabilities of EvacuatioNZ and assist in its continuing development by evaluation of possible model limitations.

EvacuatioNZ has been selected as the tool for this research, because it enables the user to consider random choices regarding exiting strategies to simulate probabilistic design scenarios with a number of uncertainties. EvacuatioNZ is a coarse network model, which represents building spaces as a network of nodes which are connected together by paths. This approach is ideal for simulation scenarios where obstacles and barriers that influence individual path route choice within a building are unknown, (i.e. internal corridors, partitions, furniture layout). A node network can be populated with agents as specified by the user.

Occupants are represented as agents and characterised with their individual behaviour and personal attributes. The user can establish agent characteristics such as: starting distance, gender, age, speed, BMI and height. The EvacuatioNZ software uses Monte Carlo methods to generate distributions of agents' properties, e.g. speed and pre-evacuation times, through the use of input data distributions. EvacuatioNZ provides an array of user-defined exit behaviour strategies that specify how an occupant would travel towards an exit node; exit behaviours such as: minimum distance to an exit, minimum number of nodes to an exit, shortest path length to a neighboring node, or specifying a particular node. Routes identified by exit signs and preferred routes can be included within a simulation.

3 BASELINE MODEL

In order to model Woolworths building egress, a Baseline Model network has been constructed to closely represent the actual building geometry. The Baseline Model incorporates direct evidence information, i.e. building layout and features, occupancy, occupants' exit preferences and reactions to the fire.

3.1 Building Geometry

Baseline Model building geometry is represented in Figure 2. The unoccupied sub-basement level has been disregarded in the Baseline Model. Basement, ground, first, and second floor were retail floors with high occupancy. The upper levels had a low occupancy. Staff on these upper levels did not hear alarm and did not escape at the same time as the majority. Most of the staff on the upper levels were rescued via the windows and roof. Estimated number of occupants in nodes shown in Figure 2.

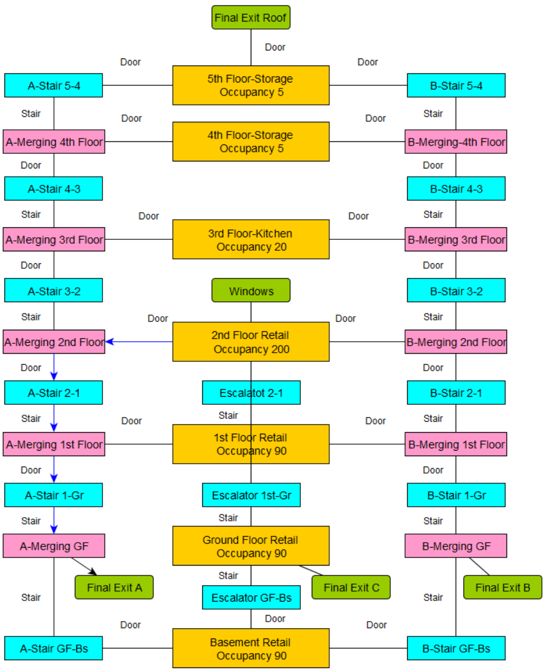

Figure 2 – Baseline Model geometry

Even though the fatalities occurred only on the second floor, and it was unlikely that upper floors effected fire egress from the building, for the completeness of the analysis seven floors were modelled.

Building floor geometry has been based on the layout and size of the second floor. Width of exit doors, stairs, and escalator is as scaled from the plan. Doors to stairs scale 1.6 m wide, the stairs scales 1.9 m wide, and the escalator width scales 1.5 m wide. Generally, flight of the stairs varies between 8 m to 10 m in length and have 300 mm x 160 mm treads and risers. It is assumed that at least 10 m distance was travelled between the floors.

Final exits from the stairway X, and Z were at ground floor discharging directly to the outside, these final exits has been represented by nodes Fire Exit A, and Fire Exit B. Stairway Y was redundant in the Baseline Model due to the locked doors and the fact that people were not able to use it. The escalator connected basement, ground, first and second floors, and was used for egress to the ground floor exit doors. The ground floor five final exit doors have been represented in the Baseline Model as Fire Exit C, with a combined width of 10 m.

3.2 Building Occupants Distribution and Agent Type

In order to simulate the evacuation as closely as possible, the ideal situation would be to have the exact number of people in each space, the exact travel distances to preferred exit, the exact pre-evacuation time, and individuals' walking speed. In order to deal with uncertainties, Baseline Model input is subject to several assumptions based on available information. The input of occupant distribution throughout the building has been based on the information given in fire investigation report [2]. Occupant distribution has been estimated as following:

- There was no public access to the upper levels, only staff were allocated to upper floors. Some of the staff used stairway B, but the majority were rescued from the roof, according to Turnbull [9] 26 people, and according to Carter [10] 27 people. It has been assumed that at least 30 staff were on upper levels.
- The report [2] stated that 6 office staff were rescued from windows on the second floor.

- 69 staff were reported to be in the building, and approximately 32 office staff were rescued via windows and roof. It has been estimated that 7 - 9 staff members would be located on each retail floor.
- Remaining 430 customers have been distributed between 4 retail floors, with the second floor being the most populated.

The probability of occupant distribution and agent types is shown in Table 1.

Agents Type:		**Type 1, public**	**Type 2, staff**	**Type 3, public/staff**	**Type 4, staff**	**Type 5, staff**
Specified Exits:		**Stair A Final exit A**	**Stair B Final Exit B**	**Escalator Final Exit C**	**Final exit Roof**	**Final exit Windows**
Occupancy per level = probability 100% per level						
Level 5	5		23%=1 staff		77%=4 staff	
Level 4	5		23%=1 staff		77%=4 staff	
Level 3	20		23%=5 staff		77%=15 staff	
Level 2	200	71%=142 public	5%=9 staff	20%=40 public/staff		4%=7 staff
Level 1	90	70%=63 public	10%=9 staff	20%=18 public/staff		
Ground	90			100%=90 public/staff		
Basement 1	90	70%=63 public	10%=9 staff	20%=18 public/staff		
Building total:	500					

Table 1 – Probability of occupant distribution and agent types

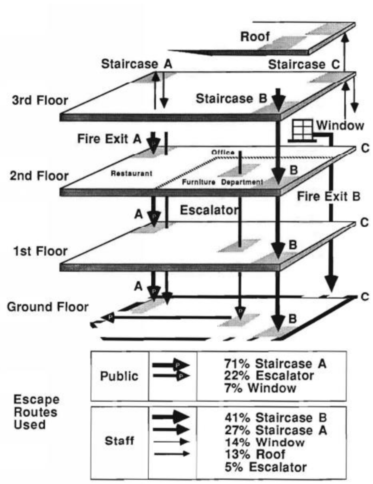

Figure 3 – Proportions of public and staff using different escape routes from the second and third floors during the Woolworths department store fire [3]

5 agent types have been created. Agent exit choices have been based on the available evidence information, Sime [3], as shown in Figure 3. The preferred route for public (agent Type 1) was staircase A, Final Exit A; and for staff (agent Type 2) staircase B, Final Exit B; also, both public and staff (agent Type 3) used escalator, Final Exit C. The ground floor staff and public used direct exits to outside, Final Exit C.

The majority of staff on upper floors used roof (agent Type 4) and windows (agent Type 5) to escape.

In Table 1, agent type probability % on the floor, has been calculated to estimated number of people, i.e. agent Type 5, 4% of 200, represents 6 office staff and 1 women in the public toilet who were rescued from the windows on the second floor [2].

3.3 Agents Properties

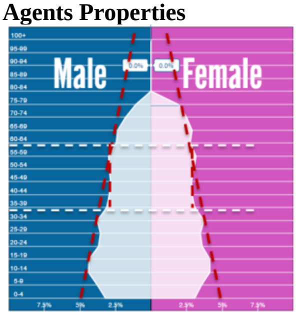

Figure 4 – UK Population Pyramid 1979 [11]

EvacuatioNZ allows to set agent type input data for gender, age and BMI, which affects the maximum walking speed of the agents. Distribution function can be used with the age and BMI elements. The gender element requires probability to be selected. For a department store in the 1970's, one might expect there to be a dominance of female occupants; however, based on general population data, up to the age of 60, male to female ratio was approximately 50:50, as shown in the UK Population Pyramid 1979 [11], Figure 4. It has been assumed that Woolworths store occupants gender would be generally in ratio 50:50.

Due to a greater uncertainty in distribution of occupants age and BMI, the Baseline Model input data probability of agent speed is taken as naturally occurring speed variations for a general population.

According to SFPE [12] the *normal distribution* is the most commonly used continuous probability density function in statistics. Its density is a function of its mean μ, and standard deviation σ. *Normal distribution* can be used validly to test hypotheses about the means of any population, even if nothing is known. Where we have to measure things like people's height, weight, or salary, the graph of the results is very often a normal curve. A sample size of at least 30 should be used to obtain an acceptable fit of the sample mean distribution to the *normal distribution*. This type of distribution is appropriate where conservative statistical values are required, when there is a wide range of random variables, and minimum and maximum variables are not defined. *Normal distribution* has been used as the best fit for this model to estimate individuals' speed. Speed has been set with mean 1.2 m/s and standard deviation 30. In order to allocate agents' travel distance to stairs, occupants have been randomly distributed across the floor area, in the model.

3.4 Evacuation Behaviors

In Baseline Model occupants have been represented by agents with given behavioral characteristics of pre-evacuation delays and route choice options. There is a high level of uncertainty in agents' pre-evacuation times. Some occupants left the store as soon as they became aware of the fire. Conditions on the second floor started to deteriorate within 3 min after ignition [1]. The majority of occupants escaped during the sounding of alarm. Some of the second floor occupants refused to leave, regardless of requests from the staff and deteriorating conditions on that floor. The Baseline Model pre-evacuation time has been set for staff and public as the triangular distribution from 0 to 6 min, with the most likely pre-evacuation time of 2 min.

3.5 Environmental Conditions

Several environmental factors may reduce an agents' maximum speed, such as movement in the smoke and reduced lighting. Visibility in the building was not generally affected, as building was provided with emergency lighting and emergency power generator. This work does not address lighting. However, evidence suggested that smoke density obstructed visibility on the second floor to 5 m [2]. The occupants on upper levels could not use stairway X, as it rapidly filled with a large amount of smoke and heat because it was the stairway most used for evacuation from the second floor and its doors remained open the longest [1].

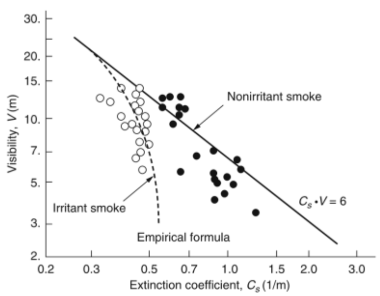

Figure 5 – Visibility of the fire exit in irritant and nonirritant smoke [13, Figure 61.11]

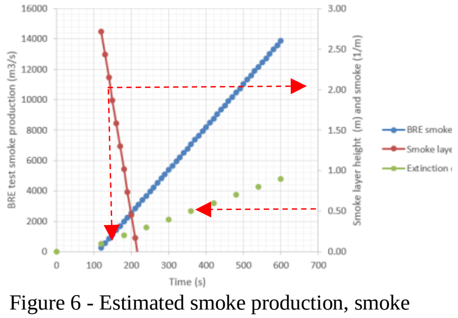

Figure 6 - Estimated smoke production, smoke layer height, and extinction coefficient

The Baseline Model incorporates an irritant smoke reduction factor for the second floor node, stairway X up to the first floor, and some reduction in stairway Z, based on evidential statements [2]. Jin's research of smoke extinction coefficient versus visibility, as shown in Figure 5, has been incorporated in the model. According to Jin's experiment with familiar (researchers) and non-familiar (study participants), most subjects began to be emotionally affected when the smoke density reached 0.1 (1/m), and a few other participants similarly affected when smoke reached an extinction coefficient of 0.2 - 0.4 (1/m). The familiar participants began to show emotional fluctuations only when smoke density reached 0.35 - 0.55 (1/m).

Jin ended test at smoke density level of 0.5 - 0.7 (1/m), when irritation to eyes and throat and suffocation were near the limit that people could not physiologically withstand.

According to Building Research Establishment (BRE), former UK government research consultancy investigation, the calculated heat output at 2.5 min reached a peak of 23 MW. Even with the fire limited to a furniture area of 3m x 3m, the experiment carried out by BRE indicated that a discharge of about 1700 m^3/min at 800 C of very dense and toxic smoke may have been present 2 minutes after ignition [2]. Estimated smoke production and smoke layer height in the second floor is shown in Figure 6.

Based on researchers' data, the Baseline Model parameters has been set according to time frame of the fire event to calibrate a time that would best correspond to observation of environmental conditions on the second floor. Smoke density (extinction coefficient) has been set progressively between 0 to 0.9 C_s (1/m).

There was not much smoke when fire was first discovered, but shortly after the fire started to produce large quantities of smoke which rapidly obscured the lights and windows and hindered the movement of people towards and through the exits from the second floor [3]. The entire second floor conditions deteriorated within 2 min after detection by the painter [2]. 3 min after ignition smoke layer was below 2 m from the floor level. According to Fire Journal [1], visibility on the second floor reduced to 5 m in 6 - 7 min. 5 m roughly correspond to 0.5 (1/m).

3.6 Estimating Number of Simulations

Each design egress simulation is a possible fire egress event. The input scenario generator, such as Monte Carlo, integrates information about uncertainty, variability, and correlation structure of the input parameters. Using Monte Carlo sampling method, a set of any given number of scenarios may be constructed. Each scenario generated will contain the typical case as well as the worst-case scenario in the tail of the distribution.

A reasonable number of simulations has been selected using Hald equation, SFPE [14]. The number of scenarios depend on the number of uncertain parameters, the average calculation time per scenario, and the statistical significance needed. Hald formula is determining the relationship between the number of runs and the statistical significance of the correlation coefficient.

$$t = \frac{c}{\sqrt{1-c^2}} * \left(\sqrt{n-2}\right) \quad \text{Equation (1)}$$

Where:	t	Confidence level, which is typically chosen as 95 %
	c	Correlation coefficient between 0 and 1. Where statistical significance does not have high value, I am taking c = 0.999
	n	Number of runs

Re-arranging equation (1) for n,

$$n = \left(\frac{t}{\left(\frac{c}{\sqrt{1-c^2}}\right)}\right)^2 + 2 = \left(\frac{95}{\left(\frac{0.999}{\sqrt{1-0.999^2}}\right)}\right)^2 + 2 = 20$$

3.7 Baseline Model Results

The EvacuatioNZ number of simulation has been set to 20, with the simulation time set to 600 s. According to Fire Journal [1], if people did not escape from the second floor in 10 min, they would not survive. The Baseline Model results are summarized in Figure 7.

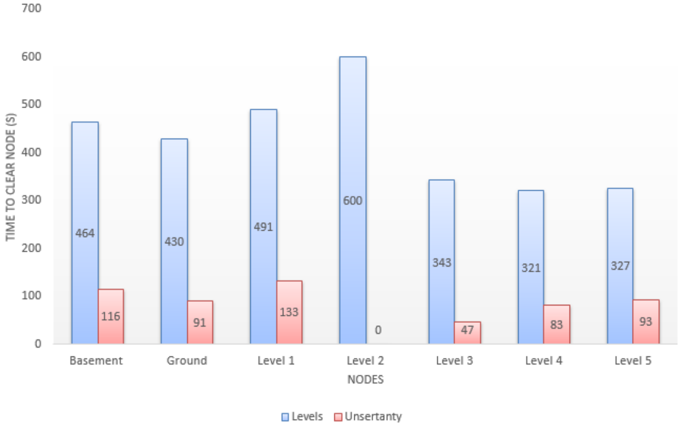

Figure 7 – Baseline Model results, mean and standard deviation in seconds

The second floor egress is the most critical to evaluate in the Baseline Model, due to the number of casualties on that floor. The Baseline Model has provided a consistent set of parameters and results which correspond well with the number of casualties on the second floor. The number of agents remaining on the second floor 5 - 6 min after the fire started is shown in Figure 8. The number of agents remaining on the second floor after 5 minutes from the fire started was on average 10.

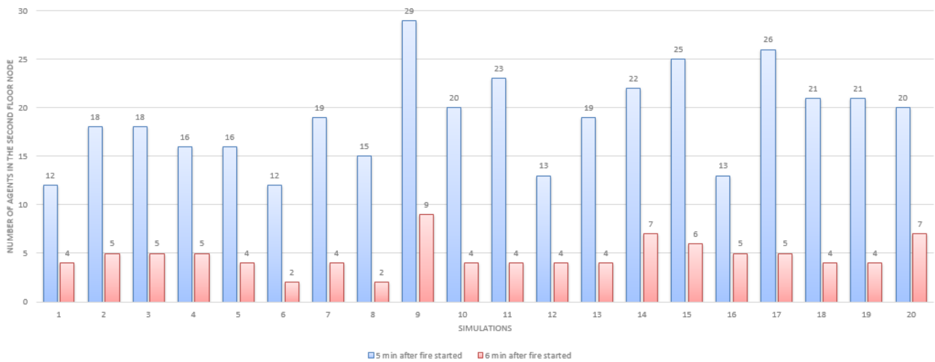

Figure 8 – Number of agents remaining on the second floor 5 - 6 min after the fire started

4 BASELINE MODEL SENSITIVITY STUDY

4.1 Building Geometry

In Baseline Model agents speed and pre-evacuation time have been set as distribution parameters. In order to get comparable results, sensitivity study modelling parameters have been set to the agent speed of 1.2 m/s, and pre-evacuation time 120 s, with only one variable parameter per simulation.

4.1.1. Coarse Network Geometry

Second floor restaurant was separated from the retail area with a 1.7 m high partition. A coarse network model approach geometry of the second floor used in Baseline Model has been a concern. Comparison of modelling the second floor as a single node, and as two nodes have been undertaken, as shown in Figure 9.

Figure 9 – Geometry of the second floor egress modelling

Comparison of results has indicated a difference of 1.5 s between the scenarios, therefore it does not really matter if the second floor was modelled as a single node or two nodes.

4.1.2. Number of Floors

The Woolworths store building comprised 8 floors. Sime statistical analysis incorporated only 5 floors. The sensitivity analysis on a reasonable number of floors has been undertaken. Baseline Model has been modelled with a different building geometry:

- Without basement,
- Without upper levels,
- Without both basement and upper levels

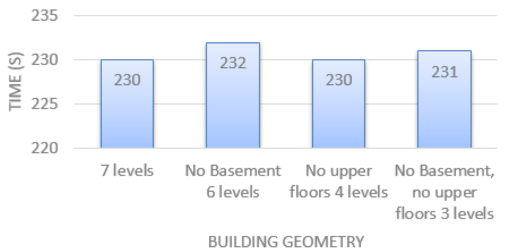

Figure 10 – Different building geometry

Results have indicated that modelling different building geometry had similar results for egress from the second floor, as shown in Figure 10.

Therefore, the Baseline Model building geometry, could have been analysed for 5 floors only, as it was previously done by Sime, but in this work, building geometry has been represented by 7 levels.

4.2 Occupancy Distribution

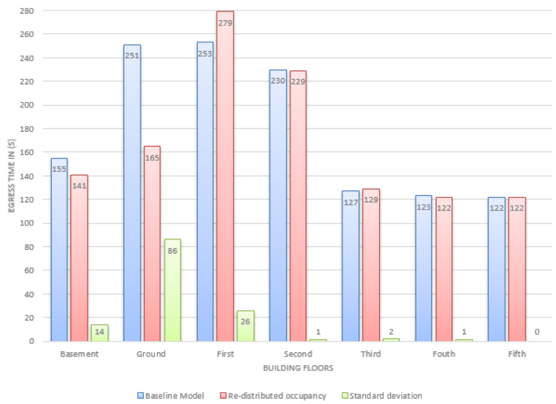

Figure 11 – Comparison of the building egress with different occupancy distribution in (s), mean and standard deviation

Another concern has been the occupancy distribution throughout the building. According to investigation Report [2] and Fire Journal [1], the second floor was the most populated. These references indicate that there was no public access to the upper floors, but according to Sime [3] the second and third floor were heavily populated by public and staff.

Sensitivity study on re-distributed building occupancy has been carried out. The Baseline Model occupancy on the second floor remained 200, first floor increased from 90 to 170 and remaining occupants have been re-distributed throughout the building.

Revised occupancy distribution across the floors provided comparably similar results for the building evacuation, and near identical result with standard deviation 1 for the second floor, as shown in Figure 11.

4.3 Model Evacuation Behaviours

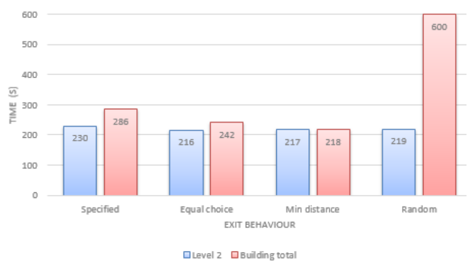

Figure 12 – Comparison of the evacuation time with various exit behaviours

Egress choices in Baseline Model have been following the diagram given in Sime [3] and represented in the model as specified exits. Sensitivity study on evacuation behaviour has been carried out. For comparison, egress has been modelled with equal exit choices between the 3 available exits as one scenario, second scenario when agents exit behavior was the shortest distance to safe, and third scenario when agents choose exits randomly. Comparison of the evacuation time from the second floor and building total, mean and standard deviation are given in Figure 12.

Modelling shows comparably similar evacuation results, however the scenario with exit behaviour random, gives longer times than other scenarios. Revising Baseline Model to random behaviour in order to have a more conservative Baseline Model is not practical, as results indicated that the pattern of behaviour cannot be limited to one floor only. Even when agents escape immediate danger they were re-entering floors, as exit choice remains random. Random scenario has been modelled to represent the situation on the second floor to allow for the scenario when people found stairway Y locked and were diverted to search for another exit. However, random choice scenario in most cases is not that useful.

Scenarios with specified exits and minimum distance to safe behaviours show a very similar outcome. In reality when people would equally use available exits is very unlikely. In reality when people would use minimum distance to safe in public building is also unlikely, as customers are generally not familiar with the building and would not be able to tell travel distance to the exit. According to Carter [10], in public buildings people normally use familiar exits, or the exit they entered the building by. Therefore, the exit choice in the Baseline Model has been represented as specified exits.

4.4 Pre-evacuation Times

Pre-evacuation times are critical to the Baseline Model. Public and staff on the second floor, despite the fact that there was adequate egress capacity, and they were the first in the building to receive environmental cues (smoke) and notification (alarmed by painter) were the most affected. It is obvious that detection, notification, and travel time phase did not play a significant role in the egress from the second floor.

It is found that where egress performance is not dominated by congestion, flow constraints, or travel distances, particular importance shall be given to factors that affect individuals' time taken to respond. Referring to SFPE [15], the factors that influence individual egress performance are, to name a few: cognitive abilities, culture, exposure to cues, fatigue, general health, sensory impairment, information levels, familiarity, role, responsibility, age, gender, activity, social affiliation, engagement, commitment, physical abilities, proximity to the incident. The EvacuatioNZ has capability to model most of these factors. Retana [16] research indicates that the parameters that affect the decision-making process of an individual have been defined, and incorporated into properties of the EvacuatioNZ. The Evacuation Decision Model (EDM) considers the evacuation decision process over time and predicts the evolution of the decision to make action based on risk perception. So far EDM was calibrated against several of the C/VM2 pre-travel activity times, using EDM function in Baseline Model would not benefit this work.

5 BENCHMARKING

5.1 Baseline Model Benchmarking

The purpose of modelling a series of evacuations from the Woolworths store was to obtain evacuation times for a variety of scenarios and to benchmark them to the actual event timeline obtained from the information in the Report [2]. Twenty possible evacuation scenarios were plotted for comparison of the results, as shown earlier in Figures 7 and 8. Figure 8 clearly shows that a number of the people were still on the second floor after 5 - 6 min, and were exposed to untenable conditions, and were unable to escape from the floor. The number of people varies with the simulation, due to the EvacuatioNZ Monte Carlo methods to generate distributions of evacuation times and speed through the use of input data distributions. It is possible to calibrate Baseline Model to get exactly 10 casualties with pre-set parameters; however, the model would not be able to evaluate all uncertainties of the fire event, which would not benefit this research.

5.2 EvacuatioNZ Limitations

The predominant research objective was to benchmark the capabilities of EvacuatioNZ and assist in its continuous development by evaluation of possible model limitations. During this research, the EvacuatioNZ model worked satisfactorily, with exception of random exit behavior, which was modelled to represent the situation on the second floor to allow for when people found stairway Y locked and were diverted to search for another exit. EvacuatioNZ did not allow to limit random behavior to one floor only, and the application of random exit choice across the building did not produced sensible results. Even when occupants escape immediate danger they were entering other floors and re-entering the second floor, as exit choice remained random. Setting model default behavior to the minimum distance to safe, and adding an option to apply random exit behavior limited to the specified node only, could improve the program capability, however random behaviour is not that useful in the reality.

6 CONCLUSIONS

This study has sought to recreate a fire emergency evacuation from the Woolworths department store applying egress model EvacuatioNZ. During this research, the EvacuatioNZ model functioned adequately.

- The results shown in this paper has demonstrated that EvacuatioNZ model is able to reasonably represent building geometry. A coarse network approach is ideal for the simulation scenarios where obstacles and barriers that influence individual path route choice within a building are unknown.
- EvacuatioNZ Monte Carlo method of generating distributions allows to assess uncertainties within the evacuation variables. The normal distribution has been incorporated in the model as the best fit for the scenario with a wide range of random variables to estimate agents speed. The triangular distribution has been used to estimate pre-evacuation time, with minimum, maximum and the most likely parameters taken

from the incident information.

- EvacuatioNZ allows to assign specific exit choices to agents, which corresponded well with Sime research on proportion of people using different escape routes.
- It allows to allocate agents' travel distances to exits as randomly distributed across the floor area in the model. This is ideal when location of people within the building spaces is unknown.
- EvacuatioNZ allows to incorporate environmental conditions in the model. In this work, Baseline Model has incorporated an irritant smoke reduction factor for the second floor and adjacent stairs.
- EvacuatioNZ has the capability to obtain a detailed log file of each agent that is included in the simulation. This capability is ideal when specific information is required on agents movements.

The current version of EvacuatioNZ can be used for design purposes. Users must know the limitations of the model inputs, and carefully assess assumptions for distribution parameters.

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