Validation of EvacuatioNZ Model for High-Rise Building Analysis

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Abstract

This thesis covers a variety of analytical approaches that validate the use of the EvacuatioNZ model on high-rise building analysis. Through performing a number of sensitivity analyses, several model deficiencies as well as functional limitations were improved upon and part of the model developments are continued based on the previous research done by two Master's students at the University of Canterbury.

In this thesis, data from three evacuations were considered for different validating aspects. These evacuations were, a hypothetical 21-storey hotel building located in the United States of America, which was previously simulated using Simulex and EXIT89; a trial evacuation that was carried out in a 13-storey office building located in Canada; and a fire drill conducted at a 21-storey office building located in Australia. Overall, the results indicated that the EvacuatioNZ is able to produce reasonable predictions of the total evacuation time regardless of the number of floors involved. The component testing also showed satisfactory outcomes regarding the involvement of disabled occupants, complexity of node configurations, and different pre-movement time distributions.

However, the current model still has a number of limitations that need to be verified and tested. These include the preferred route function and the connection problem for long stairs. Further research should also be carried out on the use of the Evacuation model on other types of building structures so as to increase the confidence level of utilizing the EvacuatioNZ model for general applications.

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1. Introduction

1.1 Background

High-rise buildings have gradually become the dominant structures in central urban areas. Even though these buildings may have adequate equipment in fire prevention, fire protection and fire suppression, some of the buildings can present unique problems and dangers. These problems lead to the greatest concern of life safety especially in the area of evacuation. In recent years, the use of computer evacuation models has become a major part of fire safety design so as to gain a preliminary understanding of different types of evacuation systems.

EvacuatioNZ is a coarse network model that incorporates node/arc configurations to entail simple and complex building structures with unlimited defined occupant groups. This model is able to generate probability distributions of evacuation times by utilizing the Monte Carlo approach for risk assessment. Several studies were carried out by Teo (2001) and Ko (2003) in the University of Canterbury to validate its functional integrity on evacuation analysis as well as modifications to its functional deficiencies. Even so, the program is still in its infancy in the analysis of high-rise building evacuations. Consequently, several sensitivity analyses and validation measures were performed in this research based on three high-rise building evacuation data. These sensitivity analyses helped to examine how the EvacuatioNZ model responds to different sources of variation in the input parameters. Also, they increase the confidence in the uncertainties of the model structures and its predictions by providing sensible verifications to its functional integrity through a series of tests.

1.2 Objectives

The main objective of this research is to try to validate the use of the EvacuatioNZ model on high-rise building analysis. In order to achieve this, several essential aspects were focused on:

- To reveal and improve the functional inefficiencies of the EvacuatioNZ model by performing a number of sensitivity analyses for the 3 buildings utilized.

  - ✓ 21-storey Hotel Building (West coast of USA)
  - ✓ 13-storey Office Building (Canada)
  - ✓ 21-storey Office Building (Brisbane, Australia)

- To state clear assumptions and limitations required for EvacuatioNZ modeling on high-rise building evacuations.

1.3 Outline of this Report

Chapter 2 – This chapter summarizes a general review on human behaviour in fires under psychological and behavioural aspects. It also describes the idea of evacuation timing and the movement of disabled occupants. Most importantly, it provides a basic understanding of the currently available evacuation models along with some examples that represent different functional features.

Chapter 3 – This chapter describes the components within the EvacuatioNZ model that need to be tested through the existing high-rise building evacuation data during the validation process.

Chapter 4 – This chapter represents an overview of the functional features within the EvacuatioNZ model, such as the input and output files. Users can adequately build up an evacuation scheme by referring to this chapter.

Chapter 5 – This chapter gives a detailed description on the analyses of the 21-storey hotel building along with recommendations for future users to take account of disabled occupants as well as complex geometry set-ups.

Chapter 6 – This chapter includes the verifications on the findings in Chapter 5, and contains the detailed analyses of the simulated results with comparisons to a real incident in a 13-storey office building. It also investigates the effect of lighting systems on occupants' travel and the total evacuation time.

Chapter 7 – This chapter further verifies the findings in Chapter 5 based on an evacuation scheme in a 21-storey office building. It also confirms the use of maximum speed distribution function within the EvacuatioNZ model.

Chapter 8 – This chapter discusses the deficiencies and limitations of the current EvacuatioNZ model (Version 1.2) that are found from the three buildings examined. It also describes some further testing that may be required to validate the use of the EvacuatioNZ model for general applications.

2. Literature Review

2.1 Human Behaviour in Fires

Research concerning psychological and behavioural response of individuals in fire incidents has been accentuated for the past 40 years corresponding to the rapid expansion of human activities, modern technologies, and structural variability. This research, mainly by questionnaires and interviews, reveals the fact that occupants behave differently in relation to their roles, personalities, education, past experience, and the existing fire situations. Nevertheless, these factors are generally considered as the contributors to the overall performance of evacuation timing and egress functions.

Bryan (2002) in his study has categorized the actions taken by the occupants involved as adaptive or non-adaptive, participative or inhibited, and altruistic or individualistic. He also states that: "Altruistic behaviour can be observed in most fire incidents, with the behavioural response of the occupants in a deliberate, purposeful manner, appears to be the most frequent mode of behavioural response. The non-adaptive flight or panic type behavioural response appears to be an infrequent, unusual, or unique participant behavioural response in most fire incidents."

Panic behaviour is considered as a major concern in fire emergencies particularly when the people are under sudden extreme stressed situation, and therefore, is generally assumed to be maladaptive, i.e., adds to the loss of life and injuries which the physically destructive agent could have caused by itself. (cited in Quarantelli, 1979). Schultz (1968) in his experiments also concluded that "Panicking is a fear-induced behaviour that is non-rational, non-adaptive, and non-social, which serves to reduce the escape possibilities of the group as a whole."

Reentry behaviour is another recognized behaviour that often occurs in fire incidents. It can be characterized as the occupant who reenters the building after safely evacuating from the scene. Statistical research has been done in both Britain and the United States regarding reentry behaviour, and has shown that “fight fire”, “observe fire” and “save personal effects” are the three major motivations for occupants to reenter the building (cited in Bryan, 2002). Even though the response of this reentry behaviour seems to be rational and is often carried out in a purposeful manner, this behaviour is generally considered as non-adaptive since it affects the overall egress efficiency of others in the building.

Further, occupants often like to group together with familiar people, such as friends and family during fire evacuation; and also travel toward familiar routes, such as their usual entrances. These actions in theory are referred to as “affiliative behaviour”, which normally has the consequences of delayed evacuation response or hindered total evacuation time.

In terms of high-rise building evacuation, the occupants’ behaviour to a fire can be more critical than in a low-rise structure. Not only are the margins for safe exiting more limited, but also the characteristics of the involving occupants can be quite varied even in the same building. Canter et al. (1980) performed several interviews with those people who have survived real fire incidents, which allowed them to model occupants’ response from the initial fire cues to the point of decision making for each individual. A general model, which is shown in Figure 2.1, was then further developed to characterize these behavioural responses with respect to their role, guiding principals, and rules. In high-rise building evacuations, occupants above the fire floor sometimes are instructed to wait and gather at the exit doors on each level until the fire floor has been cleared as shown in one of the preparing options in Figure 2.1, and the procedure is often referred to as "controlled evacuation" in the design of occupant movement. This type of evacuation design minimizes the threat level of the occupants who are in immediate danger, and consequently reduces the number of fire victims. Nevertheless, a regular evacuation drill needs to be performed and the staff or wardens should be adequately trained to optimize the efficiency of this evacuation system.

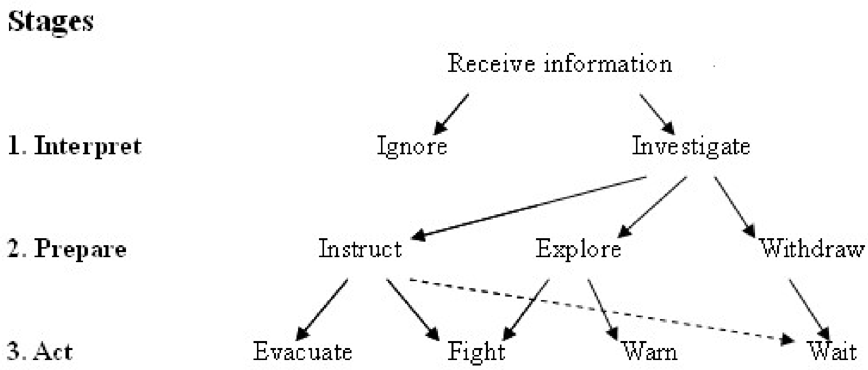


Figure 2.1: General Model of Human Behaviours in Fires. (Canter et al., 1980)

In conclusion, the behavioural response of occupants under fire conditions can have major influences on the total evacuation time. Even though it is possible to make some judgments on the actions that can be taken by the type of occupancies involved from previous research, a margin of safety should still be considered to account for the level of uncertainties. The determination of the total evacuation time is briefly discussed in the following section.

2.2 Evacuation Timing

The total evacuation time required for occupants to safely escape from a fire has always been one of the main objectives in fire safety design. It is generally considered to have its time span from the initial fire ignition to the point where a particular number of occupants emerge from the building or reach a safe destination. Theoretically, it consists of two main components: the delay time and the travel time. Proulx (2002) in her study has composed these two components into a flow chart, which is shown in Figure 2.2, to illustrate a typical evacuation sequence of human responses in fires. Besides, the chart also indicates that the total escape time available is limited by the tenability level of the environmental conditions through the exit pathways, and is generally known as the Available Safe Evacuation Time (ASET) that is often to be found by computer fire hazard analysis packages.

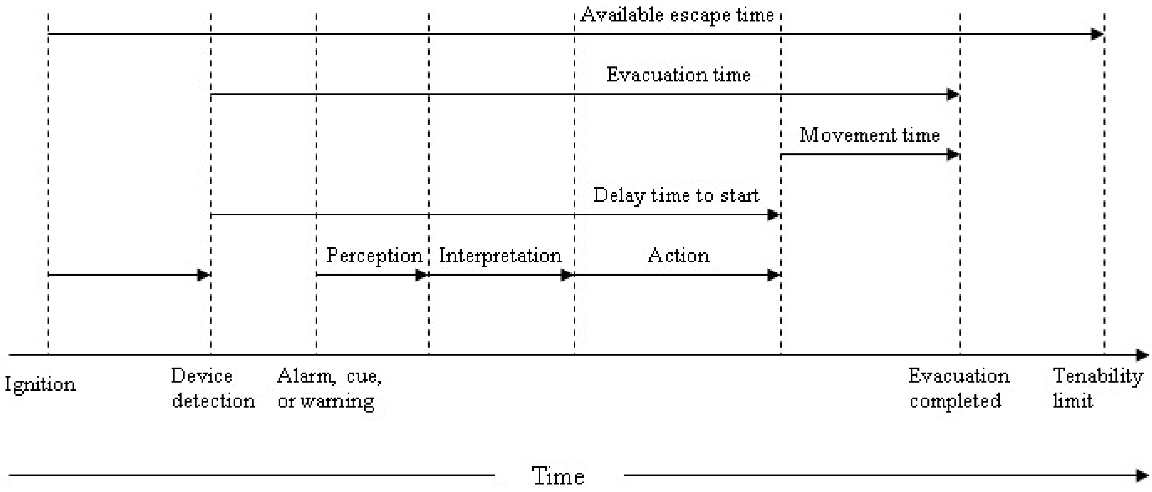


Figure 2.2: Sequence of Occupant Response to Fire. (Revised by Proulx, 2002)

Fahy (2003) has sub-divided the delay time into three minor components, which are the "time to notification", "reaction time" and "pre-evacuation activity time". These three components have significant effects on the total evacuation time, and are commonly characterized as the pre-movement time in engineering design. A typical expression of the design equation on the total evacuation time, which also includes these three pre-evacuation factors, is given by: (Buchanan, 2001)

$$t_{ev} = t_d + t_a + t_o + t_i + t_t + t_q \qquad [2.1]$$

where t_{ev} is the calculated evacuation time measured from ignition; t_d is the time from ignition until detection of the fire; t_a is the time from detection until alarm is sounded; t_o is the time from alarm until the time occupants make a decision to respond; t_i is the time for occupants to investigate the fire, collecting belongings, fight the fire; t_t is the actual travel time required for occupants to reach a place of safety, including way-finding; t_q is the queuing time at doorways or other obstructions.

Equation [2.1] is commonly referred as the Required Safe Evacuation Time (RSET), which needs to be smaller than the ASET with a safety margin in design calculations. The mid two terms, t_o and t_i, represent the pre-movement time or delay time; whereas, the last two terms t_t and t_q refer to the travel time required for the occupants to reach safe places.

In actual fact, the determination of pre-evacuation time is complex and has contained a certain level of uncertainties. Not only is it influenced by the alerting means, communication mode, and message contents, the existing environmental conditions and the characteristics of the involving occupants are also major causes to the overall estimation of pre-evacuation time.

In some circumstances, occupants may aware of the fire due to the presence of smoke, toxic gases and heat. These types of alert generally induce rapid and direct occupant responses towards the fire without any hesitation. This situation often occurs when the built environment has no installation of fire alarms or to occupants who are directly involved around the fire locations.

The most common alerting devices are through sound systems. Grace et al. (2001) in their study described informative warning systems such as Emergency Warning

Information System (EWIS) and Voice Alarm (VA) that are generally used in performance-based design particularly in large or multi-storey buildings, where the occupants may be unfamiliar with the building. Several experiments were done by researchers to investigate the response of individuals while experiencing various types of alarms. For example, Geyer et al (1988) performed some comparisons between simple tone alarms and informative warning systems in different built environments; Sime and Proulx (1991) analyzed occupants' behaviours using several different fire alarms including voice messages; Olsson and Regan (1998) did comparisons between pre-recorded VA alarm and siren type alarm under pre-trained and untrained fire warden systems. These experiments have concluded that the use of voice message is more effective than the single tone alarm systems. Occupants sometimes may wonder whether it is a burglar alarm or a false activation under a single tone alarm system, and thus will not respond directly to it unless instructed by others or when the threat becomes apparent. On the other hand, a voice message can directly tell the occupants what the emergencies are present, and what evacuation procedures they need to follow. In some circumstances, it may be more efficient to have a single tone alarm followed by a clear and direct voice message, or a combination of visual and voice alarms.

Further, delay can be contributed by several environmental means, such as the time of day, existing weather, and so on. For example, the pre-evacuation time particularly for residential buildings will be longer at nights since most occupants have to dress themselves or wake up from sleep; also, the occupants may not wish to leave the building during extreme weathers.

The characteristics of individuals or the type of occupancies are generally considered as the occupant factors that affect not only the pre-movement time, but also the total traveling time towards safe vicinities. Fahy (2003) in her study has revealed that these occupant factors consist of age, agility, responsibilities, familiarity with the building, level of emergency training, and many others. In particular, the level of mobility that correlates to each individual's traveling speed and the distance to travel have always been the major concerns in design calculations.

Overall, there are several means that contribute to the estimation of the total evacuation time. Not only do designers need to obtain a quantitative understanding of the built environment, but also the characteristics of the building occupancies should be appropriately defined. Further, the installation and the type of fire safety equipment can considerably influence the human responses, and thus the duration of the pre-movement time. Many existing evacuation models cannot yet analyze this complex response of human behaviours in relation to the estimation of total evacuation time. However, the designers should be able to provide a safety margin to account for uncertainties.

2.3 Movement of Disabled Occupants

Occupants with disabilities have been increasingly considered as an important factor during fire safety design particularly for multi-storey buildings, where the elevators may not be able to operate during fire incidents. The movement of these disabled occupants can be impaired through a variety of limitations, such as in mobility, agility, seeing, hearing, speaking, and intellectual ability. Nevertheless, it is considered that the locomotion impairment can often be the major concern among those limitations from the statistics done in Canada (Proulx, 2002).

Further, several experiments were carried out by Boyce et al (1999) to observe the characteristics of disabled occupants moving horizontally or on an incline. From their research it was found that even though the movement of the impaired persons can have a wide spectrum on horizontal and inclined surfaces, they generally cover slower travel speeds than able-bodied occupants regardless of the presence of locomotion disability. Therefore, in most evacuation model applications occupants with disabilities are characterized with slower travel speeds so as to get more conservative predictions for fire safety design. Other observed traveling speeds for disabled occupants in different types of buildings can also be referred to Fahy et al. (2001).

Occupants with locomotion disabilities often require walking aids (i.e. walking sticks, crutches, wheelchairs) particularly for horizontal travel, as referenced from the studies done by Boyce et al (1999). Thus, the density of the existing occupants where disabled people are involved can consequently be reduced causing differential effects on crowd movement, and therefore, should also be considered as an influential factor during evacuation design.

2.4 Existing Evacuation Models

In recent years, the implication of computational studies on the simulation of occupants' egress behaviours has become more and more important in life safety design particularly in complex architectural or high-rise buildings. The use of computer-based evacuation models can not only save the amount of time and cost that are required to do the actual experimental observations, the designers can also save a lot of tedious manual effort to perform intricate engineering calculations. As a consequence, several computer-based evacuation models have been developed to utilize the early hand calculation methods that are based on hydraulic flow relations, and simulate possible individual behaviours in single or crowd movements.

Olenick et al (2003) lately conducted an updated international survey of computer models for fire and smoke, and identified 16 current available egress models that are frequently used for design. It is realized that there is a trend in creating sophisticated egress functions for complex building layout with large populations. Many of these models can not only simulate psychological effects on occupants due to fire hazards, they can also provide graphical features for better observation of crowd movements.

2.4.1 Type of Evacuation Models

Due to the rapid expansion of modeling techniques, several types of evacuation models have been developed to simulate probable occupants' movement systems. These evacuation models are generally categorized with respect to their functional features, such as their inputs and outputs. Fahy (2003) in her study has defined the current available evacuation models into three categories, which are "single-parameter estimation models", "movement models" and "behavioural movement models". The single-parameter estimation models are often used to estimate movement times using simple evacuation schemes, whereas the movement models can take account of large occupancies as well as complex building geometries. The population in movement type models are generally defined globally, which means all the occupants should have homogeneous characteristics such as traveling speed. Furthermore, both the movement models and behavioural movement models are ball-bearing type models that simulate occupants in a physical way and optimize occupants' behaviour as close as possible to reality. Even though these two types of models can perform sensible analysis on the occupants' movement and behaviour, the behavioural movement models can further define different characteristics to the occupants involved and simulate individual's reactions under tenability conditions. Nevertheless, the selection of the evacuation model not only depends on the proposed outcomes, but also the quantity and quality of the data that is available to the model users.

Similar to Fahy's study, Gwynne et al (2004) also generalized three different approaches to the application of evacuation models, namely optimization, simulation, and risk assessment. The optimization models are pretty comparable to the single-parameter estimation models, which efficiently measure the total evacuation times by assuming optimal evacuation paths and occupants' characteristics without the consideration of detailed individual behaviours. The simulation models can further characterize the movement and behaviour of the occupants realistically, and therefore, represent features similar to the movement or behavioural movement models. With a further implement to the behavioural movement models, risk assessment models can not only observe the likely occupants' reactions under fire hazards, they can also perform repeated simulations to obtain probability distributions for various design changes.

For any evacuation models, the analyzing spaces within an enclosure are normally represented by two different forms: fine networks and coarse networks. Spaces generated by fine networks usually have fairly uniform distributed nodes connecting each other to create detailed external geometry layout with internal obstructions. This type of approach often needs to correlate with CAD drawings, which allow the accurate representation of the building geometries. In the coarse network approaches, spaces like a room, a corridor, a stairway, or even an entire floor can be represented as a single node. The nodes are connected by arcs with defined distances within the structure. Even though this approach requires less computational effort and has the benefit of rapid simulations, the local interacting behaviours within the individuals cannot be adequately expressed.

2.4.2 Examples of Evacuation Models

- **EXIT89** *(Fahy, 1994-2001)*

EXIT89 is designed to handle large population egress systems particularly in the area of high-rise buildings. It contains the structure of coarse network system, which divides the analyzing spaces into nodes and arcs. Consequently, the building plans cannot be imported through CAD drawings, and is not capable of visualization schemes. Even so, the program has the capability of evaluating conditional movements with the fire data imported from CFAST, and can further recalculate occupants' evacuation routes after nodes become blocked by smoke.

The program models the population in a partial behavioural way that basically depends on the relationship between occupant density and travel speed in different building components, such as stairways and doorways. The functional feature of these data inputs is based on the observations done by Predtechenskii and Milinskii (1978), which also allow the user to self-define occupants' body sizes between three variables labeled American (0.0906 m^2), Soviet (0.1130 m^2), and Australian (0.1458 m^2). Besides, each individual can either travel to the exit by the shortest route or evacuate from the user-defined pathways.

Fundamentally, EXIT89 is capable of up to 1,000 5-second time steps, 10,000 links, 20,000 occupants and 10,000 building locations. These allowable massive data inputs generally limit the desired outcomes due to insufficient storage capacity of the computer used. Furthermore, the model has its limitations to only accommodate 89 nodes on each floor, and 10 stairways within a structure.

- **Simulex** *(Thompson et al, 1994-1996)*

Simulex is an influential evacuation model that handles large population egress systems from geometrically complex structures. It is a continuous space system associated with a fine network approach. The floor plan and staircase are divided into fine grid cells that have a dimension of 0.2 by 0.2 m. The program allows the user to directly import building plans in DXF format through CAD drawings, but the information regarding the width and distance of the stairways need to be user-defined and the links between floors and exits should also be adequately specified.

Simulex is represented as a partial behaviour model that provides 2-D visualization of individual movement for the duration of an egress simulation. The occupants' travel speed is considered as a function of inter-person distance, and each individual is consisted of three circles that vary in size for different occupancies. The middle circle represents the torso, whereas the other two smaller side circles represent the shoulders. During egress simulations, these bodies are able to physically perform several behavioural movements, such as overtaking, body rotation, and side-stepping. Each individual travels to the exit according to the defined distance map, which can either be user-defined or the default distance map that leads to the nearest exit. Only a total of 10 distance maps can be used in each of the simulations, and the efficiency of the model is significantly influenced by the capacity of the computer used.

- **GridFlow** *(Bensilum et al, 2002)*

GridFlow is an object-oriented building evacuation model that combines the pre-movement and movement behaviours for a performance-based design. The individual behavioural inputs are generally straightforward, and can either be verified using empirical data or specified by the model users. The program is based on a continuous space system using fine network approach to represent the floor plan and staircase in a distance map, which is composed of 0.5 by 0.5 m grid cells. The distance map can be imported through CAD drawings, or otherwise, can be directly drawn using a graphical user interface (GUI) with GridFlow.

The individual movement relies on the population density as well as the labelled FED (Fractional Effective Dose) susceptibility in GridFlow. Purser (2002) in his research indicated that incapacitation or impairment of efficient evacuation can be predicted when FED reaches 1. On the other hand, occupants can travel to the exits either through the nearest routes, randomly distributed routes, or user-defined pathways. Further, the occupants' walking speed also incorporates with the capacity of the doors and stairways, which are evaluated by Nelson and Mowrer (2002). The model allows the user to visualize individual movement either in 2-D or in 3-D, but it is only capable of a maximum population up to 5000 occupants in the current model.

GridFlow is able to simulate irritant smoke conditions under different FIC (Fractional Irritant Concentration) levels during an evacuation. The tenability endpoint can be predicted once the FIC reaches 1. Theoretically, This FIC is calculated by summing up the fractions of an irritant concentration for each irritant present. Once the FIC reaches higher concentrations (3~5), the exposure can ultimately cause incapacitation (Purser, 2002). These outcomes, including the distributions of pre-movement, exit times and area distributions for the input population, can be exported into an Excel spreadsheet for further analysis. The program is also capable of doing several batch runs for probability distributions under different egress systems.

- **EXITT** *(Levin, 1988)*

EXITT is a behavioural evacuation model that simulates occupant reactions in fire emergencies particularly for small residential buildings. The model tracks down each individual movement based on the decision rules made by the user's judgment, case studies, or controlled experiments. The input occupant characteristics include age, gender, unimpeded travel speed, level of awareness, room locations, and the choice of assistance. Generally, occupants leave the building via the shortest routes, unless the optical density of the smoke in the pathways exceeds a certain level, then the occupants may evacuate through windows. The user may use smoke data that is imported through FAST, which divides the smoke into upper and lower layers.

The program incorporates a coarse network approach, for which the rooms, corridors, and exits can be represented as nodes, whereas the arcs characterize the distances between the nodes. Consequently, the model cannot generate accurate simulation results regarding detailed behavioural movement via obstacles. The occupants' reactions due to heat and toxicity also cannot be modeled as the current limitations. Nevertheless, EXITT can provide graphical visualization of individual movement on the computer screen.

- **EESCAPE** *(Kendik, 1995)*

EESCAPE is a movement model that simulates the time required for occupants to travel from their original position to a place of safety. It is a coarse network system with the implementation of simple node configurations. Only one exit choice is given to the occupants since the model is limited to have a single egress route. The model is not capable of analyzing conditional movements, and the building plan cannot be imported through CAD drawings. Also, the program provides no visualization of individual movement during an evacuation scheme. Therefore, EESCAPE is generally used when only the total evacuation time is desired in a simple compartment. No complex inputs are needed for building geometry and occupant characteristics.

The program models the population as a single group of occupants on each floor, and therefore, the occupants in each group are considered as a homogeneous mass traveling to the exit. The walking speed depends on the mean density of the grouped occupants, and is referenced from the calculations done by Predtechenskii and Milinskii (1978).

- **BuildingEXODUS** *(Gwynne et al, 2000-2001)*

BuildingEXODUS is a behavioural model that utilizes a fine network approach. It consists of six submodels named Occupant, Movement, Behaviour, Toxicity, Hazard, and Geometry. These submodels form a network that incorporate with one another to pass information within an evacuation system. Practically, the model is capable of simulating large populations to evacuate from a variety of enclosures by using node/arc configuration in 2-D spatial grid structure, for which the detailed geometry layout can be imported through CAD drawings. The program also comprises conditional behaviour under different levels of toxic gases, smoke concentration, and temperature. Similarly, users can either functionally input these fire data manually based on the experimental results, or conveniently imported from other fire models.

In terms of occupant movement, BuildingEXODUS is able to simulate body interferences, such as side stepping, overtaking, etc. These interferences incorporate with occupant travel speed as well as their capability of presenting specific maneuvers during an evacuation system. Basically, the program allows the user to set six different levels of walking speed either in groups or in individual. These six levels are fast walk (1.5 m/s), walk (90% FW – fast walk), leap (80% FW), crawl (20% FW), stairs-up, and stairs-down. Moreover, the exit behaviour of the involving occupants can be viewed locally or globally in 2-D or 3-D visualization through the program. Even so, the modeling of the conditional behaviours is not only limited by the capacity of the processing computer, but also relevant to the installed version of the BuildingEXODUS program.

3.0 EvacuatioNZ Model

3.1 Background

EvacuatioNZ is a coarse network model that simulates the occupants' behaviour as well as the evacuation times to the exits during an evacuation process. The program incorporates the Monte Carlo approach with unlimited simulations that generate probability distributions for risk assessment. It is written in C++ language, which can easily be modified or developed for further research. C++ is also a common language code that is widely used in the engineering field, and is able to link with other language codes if applicable. The current EvacuatioNZ model for the validation of this research is Version 1.2.

EvacuatioNZ has the benefit of analyzing large population egress systems in complex building structures. Even though the program allows unlimited numbers of defined nodes and occupants, the extent of available outputs are limited by the capacity of the PC used. Further, the model also provides the advantage of generating different design scenarios in respect to human characteristics, building structures, occupants' movement, or model mechanisms without complex alteration of the model inputs.

With the intention of improving the validity of this model to a variety of scenarios, this model has been investigated and modified by Teo (2001) and Ko (2003) during the last few years in the University of Canterbury. The basic mechanics of the model are detailed in Teo's (2001) research, which includes the moving mechanisms from node to node, travel speed incorporating Nelson and MacLennan's flow equations, etc. These components were found to work satisfactorily by Teo (2001), and had been further verified by Ko (2003) from trial evacuations.

3.2 Input Files

The current EvacuatioNZ model consists of 6 input files, which are related to the building space, occupant characteristic and movement, and simulation mechanisms. These input files are named: MAP, POPULATE, SIMULATION, SCENARIO, PERSON TYPE, and EXIT BEHAVIOUR. Functionally, these files can be sub-divided into two categories, which are in terms of the physical aspects to the defined scenarios and the behavioural aspects of the occupants concerned. Further, these files are formatted in Extensible Mark-up Language (XML), which is related to the HyperText Markup Language (HTML). In order to reduce the possibility of input errors, it is beneficial for the user to have some basic understanding of using these types of language formats.

3.2.1 Physical Aspects

(a) MAP file

The MAP file is a dominant input for the operation of the evacuation simulations. It defines the building spaces as well as the connections between each floor and stairways. Depending on the user, the room, corridor, stairway, or even the entire floor can be defined as a single node, and each node should have a name associated with a reference number, dimensions, and type if necessary (e.g. safe node). The nodes are connected through paths with specified distances and pathway configurations. Currently the model allows two types of connection between each node, such as a door that constricts the flow or stairs that are on a slope. Users can create multiple paths that lead towards or away from a node, and several connections can be formed between two nodes with different configurations.

A sample of the MAP file is illustrated below. The users can simply disregard a node by converting its existence to “No” feature and consequently create a different scenario regarding escape route under tenability conditions. For example, the user can assume a corridor or a stairway is blocked by smoke and no occupants can evacuate through that defined node.

```
    <Description>FEDG Example</Description>
    <Node exists="Yes">                                  ← Node existence – “Yes” or “No”
        <Name>Room</Name>                                ← Node name – defined by the user
        <Ref>1</Ref>                                     ← Node reference number – generally starts from 1
        <Length>10</Length>                              } Node dimensions
        <Width>10</Width>                                }
    </Node>
    <Node exists="Yes">
        <Name>Stairs</Name>
        <Ref>2</Ref>
        <Length>10.0</Length>
        <Width>1.2</Width>
    </Node>
    <!-- The exit Node -->
    <Node exists="Yes">
        <Name>Exit</Name>
        <Ref>3</Ref>
        <NodeType>Safe</NodeType>                        ← Safe node – must be defined in any simulations
        <!-- dimensions are not required for a safe Node -->
    </Node>
    <Connection exists="Yes">                            ← Connection existence – “Yes” or “No”
        <Name>TheLink</Name>                             ← Connection name – defined by the user
        <NodeRef>1</NodeRef>                             } Connecting nodes
        <NodeRef>2</NodeRef>                             }
        <Length>20.0</Length>                            ← Distance between nodes
        <ConnectionType type="Door">                     } Door details
            <Width>1.0</Width>                           }
        </ConnectionType>                                }
    </Connection>
    <Connection exists="Yes">
        <Name>TheClimb</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>3</NodeRef>
        <Length>10.0</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
        <ConnectionType type="Stairs">                   } Stair details
            <Tread>0.28</Tread>                          }
            <Riser>0.18</Riser>                          }
        </ConnectionType>                                }
    </Connection>
</EvacuatioNZ_Map>
```

(b) POPULATE file

The number and type of occupants are always the essential components that need to be specified in an evacuation simulation. POPULATE file governs these components with various optional inputs in relation to occupant number and node type. Functionally, several types of occupancy can be specified within each node with defined probabilities that add up to 100 percent, but the characteristics of the occupancy are defined in the PERSON TYPE file, which relates to the behavioural aspects. Additionally, the model can generate log files to examine occupants' movements and decision making processes by converting the log option to "Yes" function. The detailed constructions of those optional inputs in the POPUTATE file are illustrated as follows:

<u>Occupant Number</u>

The occupants in each node can be populated either in a fixed number or in a distribution. The current model allows the user to input five types of distribution, which are normal distribution, lognormal distribution, uniform distribution, Weibull distribution, and triangular distribution. Samples of the input method for these three options are shown below.

Only defines a single value

- Fixed:

```
<People>58</People>
```

Normal distribution with mean and SD

- Distribution:

```
<People>
        <Distribution type="normal">
        <Mean>30</Mean>
        <StandardDeviation>5</StandardDeviation>
        </Distribution>
</People>
```

Lognormal distribution with mean and SD

```
<People>
        <Distribution type="lognormal">
        <Mean>30</Mean>
        <StandardDeviation>5</StandardDeviation>
        </Distribution>
</People>
```

Uniform distribution with upper and lower limits

```
<People>
        <Distribution type="uniform">
        <Min>20</Min>
        <Max>50</Max>
        </Distribution>
</People>
```

Triangular distribution with upper limit, lower limit, and a most likely value.

```
<People>
        <Distribution type="triangular">
        <Min>0</Min>
        <Max>100</Max>
        <MostLikely>30</MostLikely>
        </Distribution>
</People>
```

Weibull distribution with the two functional parameters "alpha" and "beta".

```
<People>
        <Distribution type="weibull">
        <Alpha>100</Alpha>
        <Beta>3</Beta>
        </Distribution>
</People>
```

<u>Node Type</u>

The program can reduce the computational effort to input occupant numbers into each single node by creating "apportion" and "range" types of node configurations. Once the occupant number is determined, the defined occupants can be randomly apportioned over a range of nodes; or otherwise, the same number of occupants can be applied to the defined node range. The sampling input for these three types of node configurations are shown below.

- <Node type="single">1</Node> — Occupants are only defined within a single node
- <Node type="apportion">1 5</Node> — The defined number of occupants is randomly distributed to nodes 1, 2, 3, 4, & 5.
- <Node type="range">1 5</Node> — Nodes 1, 2, 3, 4, & 5 have the same number or same distribution of occupants defined previously.

PersonType Probability

As mentioned previously, the EvacuatioNZ model has the advantage of defining several types of occupancies within a single node as long as the selected probabilities add up to 100 percent. A sample input of POPULATE file along with the probability distributions is shown below.

```
<Definition>
        <People>58</People>
        <Log>no</Log>
        <Node type="single">1</Node>
        <PersonType>
                <Name>Normal</Name>
                <Probability>92</Probability>
        </PersonType>
        <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
        </PersonType>
</Definition>
```

Occupant Number – fixed or distribution

Log file – “Yes” or “No”

Single, Apportion, or Range type

Type 1 occupants

Type 2 occupants

(c) SIMULATION file

The SIMULATION file allows the user to control the modeling mechanisms for each simulation, such as the maximum simulation time, time step, maximum node density (MND), local occupant density (LOD), and door flow correlation. The MND defines the maximum number of occupants that are allowed to enter a node, whereas the LOD deals with the local door queue densities of the existing crowd.

Practically, the program utilizes two approaches to define occupant densities, such as the nodal density approach and the connection density approach. The nodal density approach can produce a reasonable assumption at the beginning of an evacuation system when the occupant density in that node is treated as the MND value. However, once the occupants start to travel towards the exits the density increases due to the existing crowd. This increased density can be appropriately modeled using the connection density approach at the exit doors, which is considered as the LOD value.

A graphical representation of the difference between these two approaches is shown in Figure 3.1 (extracted from Teo, 2001).

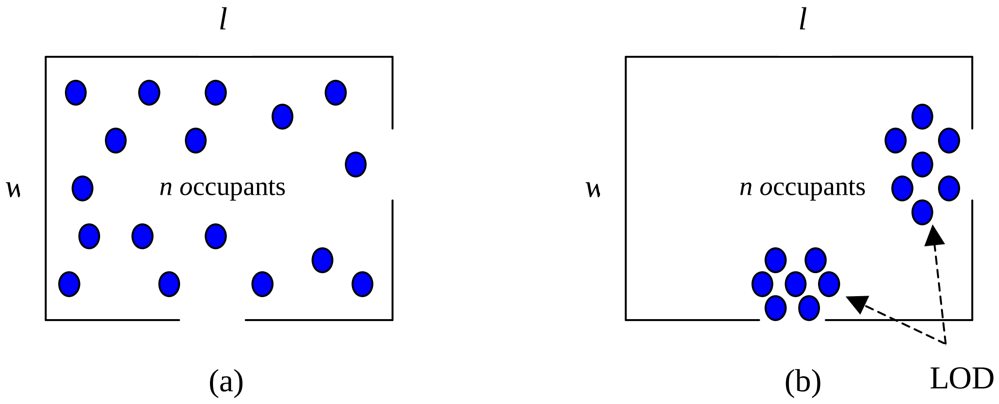


Figure 3.1: Difference between (a) Nodal Occupant Density Approach and (b) Connection Occupant Density Approach.

Teo (2001) performed some sensitivity analyses for these two approaches and found that using a mixed correlation (MND and LOD) can give more logical and realistic results. Due to the fact that the characteristics of the occupants can vary in different circumstances, the specification of the LOD can still be difficult. In this research, further analyses were carried out to look at how the LOD might vary on account of disabled occupants. Realistically, occupants with disabilities may occupy larger spaces particularly for those who are with walking aids (i.e. crutches, wheelchairs, etc.), and therefore, require smaller LOD to enlarge the average occupying space at the exits (as shown in the figures below). The detailed analyses for the suggestion values of LOD are briefly described in the next chapter.

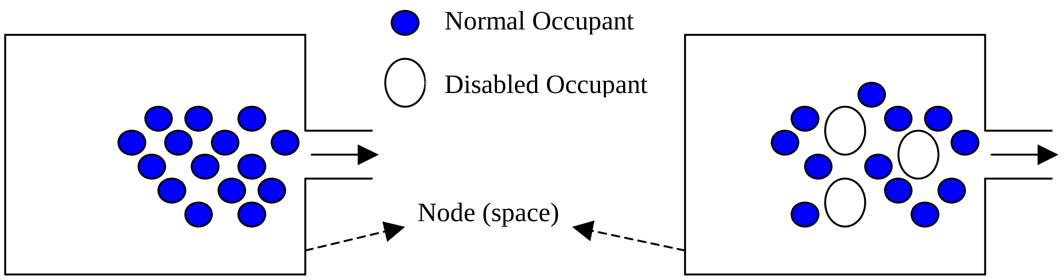


Figure 3.2: Able-bodied Occupants Only.

Figure 3.3: Mixed with Disabled Occupants.

Furthermore, there are two alternatives for the user to decide on, the door queuing mechanisms such as the McLennan door flow correlation and the Holmberg door flow correlation. Teo (2001) performed some tests regarding the functional efficiency of these two components in EvacuatioNZ, and found out that using the McLennan door flow correlation seemed to give more representative results concerning door flows. A sample of SIMULATION input file is shown below

Maximum simulation time for each iteration process

```
<EvacuatioNZ_Simulation version="1.2">
        <TimeMax>10000</TimeMax>
        <TimeStep>1</TimeStep>
        <MaxNodeDensity>2.5</MaxNodeDensity>
        <DoorFlow>MacLennan</DoorFlow>
        <OccupantDensityModel localOccupantDensity="2.2">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

Iteration time steps

Defines the maximum allowable density of occupants in a node (ppl/m^2)

Occupants door queuing correlations
- MacLennan door flow approach
- Holmberg door flow approach

Deal with local door queue densities
- Nodal density approach
- Connection density approach
- Mixed

(d) SCENARIO file

The SCENARIO file allows the user to input a defined number of simulations that is able to create a set of probability distributions by activating the dump evacuation times, which is considered as an output reporting option shown in the following example. Occupants can also be randomly distributed with their starting positions once the functional feature is activated, and thus the file generates different traveling distances to the exits as well as the total evacuation times. A detailed explanation of this random start function was discussed in Teo (2001).

Moreover, the program can produce a list of total evacuation times for the number of simulations either in a Microsoft Excel spreadsheet (.csv) format or in log text file (.txt). Users can also define the names of the Simulation and Populate files in XML format. A sample of the SCENARIO file is shown below.

Number of simulations

Generating probability distributions
- "Yes"
- "No"

Random start function
- "Yes"
- "No"

```
<EvacuatioNZ_Scenario version="1.2">
        <Simulations>100</Simulations>
        <DumpEvacuationTimes>Yes</DumpEvacuationTimes>
        <RandomStartPosition>Yes</RandomStartPosition>
        <Files>
                <Simulation>simulation.xml</Simulation>
                <Populate>populate.xml</Populate>
        </Files>
</EvacuatioNZ_Scenario>
```

Output files

3.2.2 Behavioural Aspects

(a) PERSON TYPE file

The PERSON TYPE file allows the user to define several kinds of occupant with different characteristics in relation to the maximum potential speed and the type of pre-evacuation distribution. Functionally, the potential speeds for the occupants involved are calculated using Nelson and MacLennan equations that are limited by the defined maximum value. In the latest version, users are able to define a range of maximum potential speed distributions in order to create more realistic situations, such as normal distribution, lognormal distribution, uniform distribution, triangular distribution, and Weibull distribution. Nevertheless, Lam et al (2006) found that when occupants travel horizontally or on stairs all walking times data can be well represented by a normal distribution.

Likewise, the pre-evacuation times in the current model can also be defined using the five distributions described. Samples of the data input for the specified options are illustrated as follows.

Maximum Potential Speed

The maximum potential speed can either be fixed or in distributions.

- Fixed:

```
<Speed>1.5</Speed>
```

Only defines a single value

- Distribution:

Normal distribution with mean and SD (Recommended)

```
<Speed type="distribution">
        <Distribution type="normal">
        <Mean>1.5</Mean>
        <StandardDeviation>0.2</StandardDeviation>
        </Distribution>
</Speed>
```

Pre-evacuation Time Distributions

The data inputs for the five pre-evacuation time distributions are listed below.

- Lognormal:

```
<PreEvacuation type="distribution">
        <Distribution type="lognormal">
        <Mean>180</Mean>
        <StandardDeviation>60</StandardDeviation>
        </Distribution>
</PreEvacuation>
```

- Normal:

```
<PreEvacuation type="distribution">
        <Distribution type="normal">
        <Mean>180</Mean>
        <StandardDeviation>120</StandardDeviation>
        </Distribution>
</PreEvacuation>
```

- Uniform:

```
<PreEvacuation type="distribution">
        <Distribution type="uniform">
        <Min>0</Min>
        <Max>662</Max>
        </Distribution>
</PreEvacuation>
```

- Triangular:

```
<PreEvacuation type="distribution">
        <Distribution type="triangular">
        <Min>0</Min>
        <Max>662</Max>
        <MostLikely>400</MostLikely>
        </Distribution>
</PreEvacuation>
```

- Weibull:

```
<PreEvacuation type="distribution">
        <Distribution type="weibull">
        <Alpha>233</Alpha>
        <Beta>3</Beta>
        </Distribution>
</PreEvacuation>
```

EvacuatioNZ allows the user to extract the pre-evacuation times simulated during an evacuation process into a Microsoft Excel spreadsheet (.csv) by creating a dump pre-evacuation time in the SCENARIO file. The entry code is shown below.

```
<DumpPreEvacuationTimes>Yes</DumpPreEvacuationTimes>
```

The user can decide whether or not a simulation result for the defined pre-evacuation time distribution to be exported into an Excel spreadsheet.
- "Yes"
- "No"

For further clarity of the data inputs, a full sample version of PERSON TYPE file is shown below. Users can alternate the input options for the maximum potential speed and pre-evacuation time distribution using the codes specified previously.

Maximum potential speed
- Fixed
- Normal distribution

The exit behaviour is defined in the EXIT BEHAVIOUR file.

5 choices of pre-evacuation time distribution as described earlier.

Normal occupants:

```
<EvacuatioNZ_PersonType version="1.2">
        <PersonType name="Normal">
                <Speed>1.5</Speed>
                <ExitBehaviour>Default</ExitBehaviour>
        <PreEvacuation type="distribution">
                <Distribution type="normal">
                <Mean>180</Mean>
                <StandardDeviation>120</StandardDeviation>
                </Distribution>
        </PreEvacuation>
        </PersonType>
```

Disables:

```
        <PersonType name="Disable">
                <Speed>0.7</Speed>
                <ExitBehaviour>Default</ExitBehaviour>
        <PreEvacuation type="distribution">
                <Distribution type="normal">
                <Mean>180</Mean>
                <StandardDeviation>120</StandardDeviation>
                </Distribution>
        </PreEvacuation>
        </PersonType>
</EvacuatioNZ_PersonType>
```

(b) EXIT BEHAVIOUR file

The EXIT BEHAVIOUR file allows the user to specify a number of exit behaviours with probabilities that add up to 100 percent for each type of occupant group defined. The current version is capable of identifying more than one occupant group which have different exit behaviours with user-defined names in each simulation. These names are then to be called out in the PERSON TYPE file as one of the occupant characteristics. Functionally, there are 8 types of exit behaviour that are available in the latest version. These behaviours are the First Route, Preferred Route, Exit Sign Route, Shortest Path to Next Node, Minimum Nodes to Safe Route, Minimum Distance to Safe Route, Random Route, and None. A detailed description and the input codes for these types of exit behaviour are summarized as follows:

- First Route – “First”

In many cases, individual occupants may not be familiar with the building exits, particularly in public structures. Whenever there are multiple exit routes under this situation, often those individuals will choose the exit route that they first become aware of. This type of behavioural function is correlated with the connection orders in the MAP file for the relevant nodes. However, this mode is generally not recommended for most practical uses.

- Preferred Route – “Preferred”

This type of escape function is generally to be used under two circumstances. The first circumstance can be directly interpreted from the name of the function “preferred”, for which occupants egress from the building with familiar exit paths; whereas, the second circumstance is when the occupants are instructed or forced to egress from a certain exit route due to safety procedures or even tenability conditions. Even though this function is generally useful in designing means of escape, it still requires further enhancement of its functional integrity. A sample of the data input with a defined preferred route in the MAP file is shown below.

The preferred route is specified in the connections.

```
<Connection exists="Yes">
        <Name>TheLink11D</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>5</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.1</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
```

- Exit Sign Route – "ExitSign"

This code models the occupants to evacuate with the indication of exit signs, which happens mostly in large public structures such as shopping malls, theatres, clubs, etc. The input of this function should incorporate the specified connection choice in the MAP file, which is illustrated below.

The ExitSign function should be specified in the connections, and has similar inputs to the preferred route.

```
<Connection exists="Yes">
        <Name>TheLink11D</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>5</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.1</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
```

- Shortest Path to Next Node – "ShortestPathToNextNode"

As described earlier, users can construct several connections between two nodes with different distances. Once this type of exit behaviour is defined, occupants can only choose the shortest path that leads to the next available node. However, this function is still in its infancy, and further validation procedures should be carried out to implement this functional feature.

- Minimum Nodes to Safe Route – “MinNodesToSafe”

In some circumstances, occupants who are familiar with the built geometry can travel around the building to reach a safe location through minimum spaces. These spaces, such as rooms, corridors or stairways, can be defined as nodes with specified dimensions in MAP file. Even though the occupants can arrive at the safe node through the minimum number of nodes, the traveling distance is not necessarily the shortest. In other words, the traveling distance in a node can be longer than the total traveling distance in two or more nodes that lead to the same destination.

- Minimum Distance to Safe Route – “MinDistanceToSafe”

With familiarity of the built structure, occupants can travel to the safe places through the shortest exit paths. Functionally, this exit behaviour is quite distinct from the shortest path to next node and the minimum nodes to safe route. On one side, occupants defined with minimum distance to safe node do not necessarily choose the shortest route to the next available node. They may actually choose a longer path to reach another available node that leads nearer to the final exit. On the other hand, occupants may pass more nodes than the minimum required reaching the safe node as long as the overall distance is kept to the minimum.

- Random Route – “Random”

Occupants can be defined to randomly choose their exit paths among the available routes in each node.

● None – “None”

Once this exit behaviour function is specified, occupants are not permitted to leave their current node through the available paths. This situation often happens when all of the exits around the room are blocked due to untenable conditions causing the occupants unwillingly to leave the room.

A sample data inputs for the EXIT BEHAVIOUR file is shown below.

```
<EvacuatioNZ_ExitBehaviour version="1.2">
        <ExitBehaviour name="Default">
                <ExitBehaviourType type="MinDistanceToSafe">
                        <Probability>50</Probability>
                </ExitBehaviourType>
                <ExitBehaviourType type="Random">
                        <Probability>50</Probability>
                </ExitBehaviourType>
        </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

Incorporate with the name defined in the PERSON TYPE file.

Probabilities add up to 100 percent under this exit behaviour name

3.3 Output Files

The current EvacuatioNZ is able to generate three major output files in Comma Separated Values (CSV) form, and one LOG file in text document form. These CSV files named CONNECTIONS, LOG ACTION and NODES can directly be imported into the Excel spreadsheet for users to observe and generate probability distributions for risk assessment; whereas, the LOG file provides a detailed description for each simulation performed, which includes the time when the simulation is run, the status of the input and output files, the number of occupants evacuated, and also the total evacuation time.

The CONNECTIONS file records the flow of the occupants through each connection at each time step, and consequently shows the utilization of each exit path during an evacuation. The NODES file provides similar information to the CONNECTIONS file except it is emphasized in each node. This file allows the user to observe the potential bottleneck in the building structure, and further identify the usage of each node in correspondence to the populate quantity for an egress system. The LOG ACTION file gives the probabilities of several actions that are likely to be performed by the occupants involved in the fire, and the probabilities at each time step should add up to 100 percent. Nevertheless, most of the behaviours cannot yet be simulated using the current version due to incomplete programming of the LOG ACTION file.

There are some other output files available regarding occupants pre-evacuation times specified in the PERSON TYPE file, total evacuation times for batch runs generated through SCENARIO file, and log files with detailed individual movements defined in the POPULATE file.

4.0 Component Testing

Teo (2001) and Ko (2003) have verified the proper performance of many of the basic flow components and the occupants' behavioural functions (i.e. delay time, exit choice, etc.) in EvacuatioNZ. The model was then capable of generating rational predictions with the available functional inputs for plain evacuation systems. Through this research, the program has been further developed to improve its functional integrity, and therefore, becomes more competent at realistically modeling occupant movements.

The testing scenario carried out in this section is based on a simple evacuation system that was extracted from an example in the Fire Engineering Design Guide (FEDG) by Buchanan (2001). The simple evacuation system only has a room connected to a stairway, which leads to the final exit as shown in the figure below.

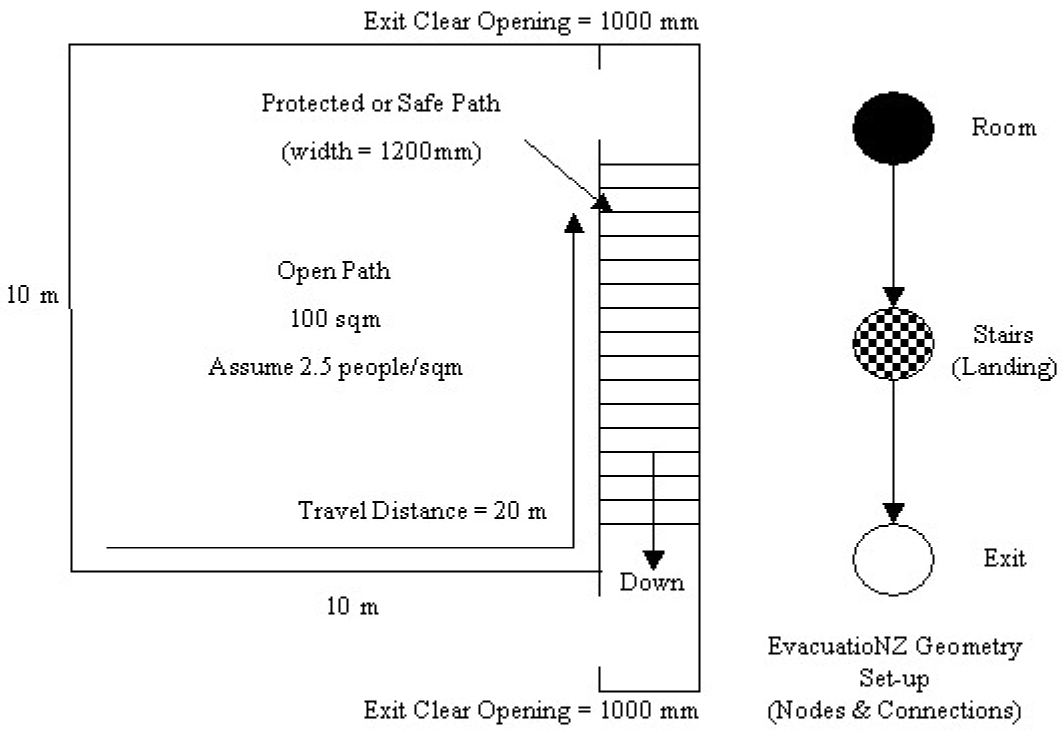


Figure 4.1: A Graphical Representation of the Simple FEDG Evacuation System. (Buchanan, 2001)

4.1 Pre-movement Time Distribution Function

The older version of EvacuatioNZ (Version 1.01) model was only capable of generating normal and uniform pre-movement time distributions. After Ko's (2003) research, the model was further developed to incorporate three other types of pre-movement time distribution functions, such as the lognormal, triangular, and Weibull distributions. Some tests were carried out to review the integrity of these five pre-movement time distribution functions based on the FEDG evacuation system.

Practically, the shape of the probability distribution for the simulated delay periods may not look like its defined distribution type while a limited number of occupants are involved. Thus, 300 occupants were assumed in this evacuation scheme rather than 90 occupants as in the original example (i.e. 0.9 people/sqm in Buchanan, 2001). Even though it may seem somewhat unrealistic for this size room to contain this many occupants and the average travel distance is unreasonably long for the occupants involved, these considerations should have no effect on the results of the simulated pre-movement times. The randomly chosen testing parameters for these distributions are listed as follows:

● Normal distribution:	mean = 150 s	SD = 20 s
● Lognormal distribution:	mean = 150 s	SD = 20 s
● Uniform distribution:	min. = 0 s	max. = 200 s
● Triangular distribution:	min. = 0 s	max. = 200 s
	most likely = 100 s	
● Weibull distribution:	alpha = 150	beta = 3

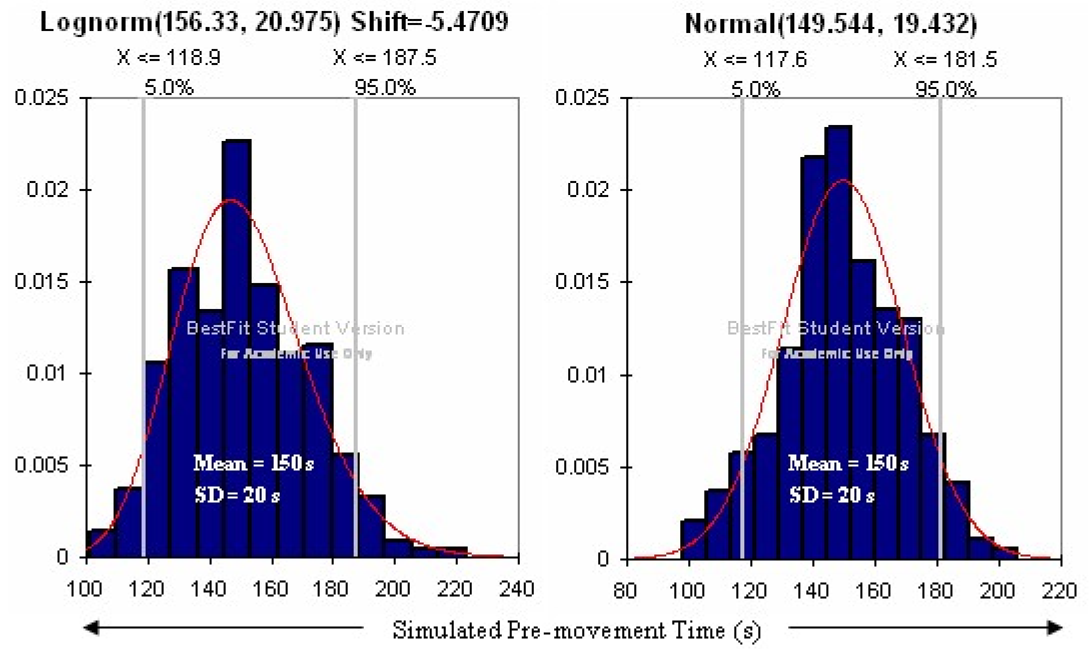


Figure 4.2: The Distributed Results of the Pre-movement Times for the 300 Occupants involved using Lognormal and Normal Distribution Functions.

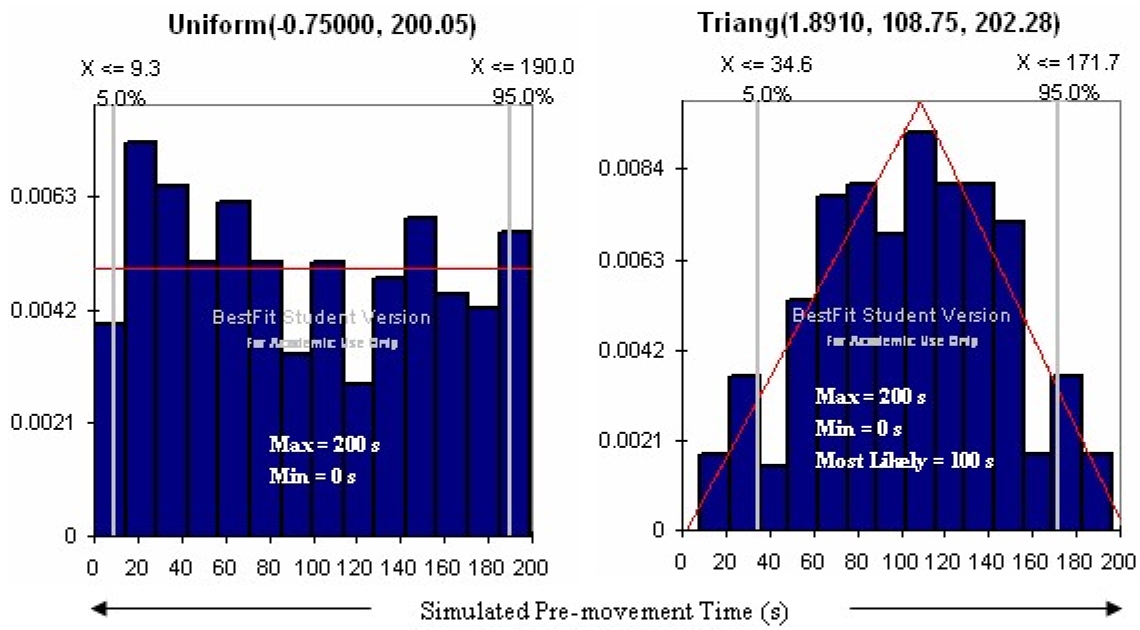


Figure 4.3: The Distributed Results of the Pre-movement Times for the 300 Occupants involved using Uniform and Triangular Distribution Functions.

Figure 4.2 ~ Figure 4.4 represent the simulation results for the five distribution functions using EvacuatioNZ. As shown in these figures, the pre-movement times generated for the 300 occupants have formed a distributed shape according to their respective function. The distributed range of the simulated pre-movement times in each distribution function also corresponds satisfactorily to its defined parameters. Thus, the functional inputs for the pre-movement time distributions within the EvacuatioNZ model have been verified for their appropriate use for general applications

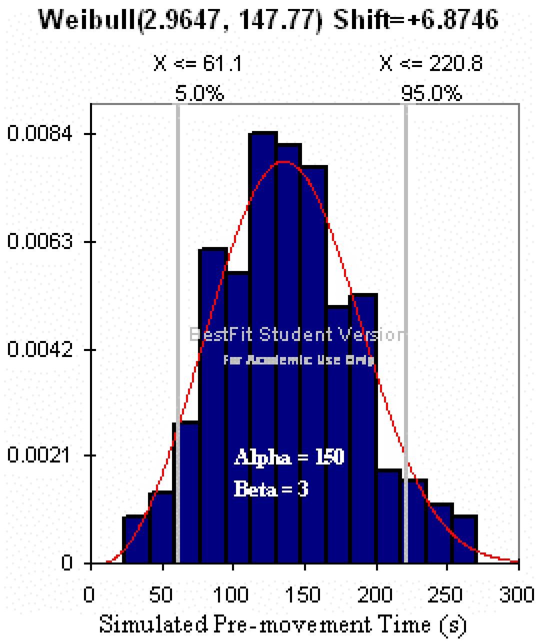


Figure 4.4: The Distributed Results using Weibull Distribution Function.

On the other hand, it should be noted that these five distribution functions can also be applied to the occupants' maximum travel speed. This maximum travel speed incorporates similar input parameters for each distribution function, and the shape for each type of the distribution consequently gives the same performance to the pre-movement time distributions.

Further verifications for these distribution functions regarding pre-movement time and maximum travel speed are to be discussed during the sensitivity analyses of the three high-rise building utilized.

Refer to Appendix A for the detailed EvacuatioNZ input files regarding this component testing.

4.2 Lighting System in the Stairwells

In fact, the occupants' speed of movement may be significantly influenced by the existing lighting conditions, and consequently cause substantial impact on the performance of safe evacuation. However, not many studies have been performed regarding this issue that allows the current evacuation models to incorporate this functional input. In this research, one of the referenced building evacuation data sets has touched on some of the lighting systems in the stairwells, and therefore, has enabled us to have a fundamental review of their effects on the total evacuation time.

Using the MAP input file, the current EvacuatioNZ model (Version 1.2) has been developed to incorporate four different lighting conditions in the stairwells. The values used to adjust the movement speeds under these lighting systems are based on the report "Assessment of Photoluminescent Material during Office Occupant Evacuation" by Proulx et al (1999). The light output for each lighting system and the recorded experimental results are summarized below:

- Stairwell A: Emergency Lighting (EL) = 57 lux
- Stairwell B: Full Lighting (Full) = 245 lux
- Stairwell C: Photoluminescent without any Lighting
- Stairwell D: Photoluminescent & Emergency Lighting = 74 lux

Stairwell	Density (ppl/m^2)	Observed Mean Speed (m/s)	Calculated Speed* (m/s)
A (EL)	1.25	0.70	0.72
B (Full)	1.30	0.61	0.70
C (PLM)	2.05	0.57	0.49
D (PLM + EL)	1.00	0.72	0.79

Table 4.1: Speed of Movement in the Four Stairwells. (Proulx et al, 1999)

* **Equation:** Speed = 1.08 – 0.29 × Density for the movement of occupants going down stairs under normal conditions (Proulx et al, 1999).

Based on the experimental results it is possible to normalize the ratio of the observed and calculated speeds in Table 4.1 to the full lighting system. This will produce the adjustment factors as shown in Figure 4.5. This figure clearly indicates that occupants' speed can mostly be affected under PLM, whereas the combination of PLM and EL has the least impact on the occupants' travel. Nevertheless, it should be noted that these adjustment factors only alter the maximum movement speed for the effect of lighting within the EvacuatioNZ model regardless of the density of the existing crowds.

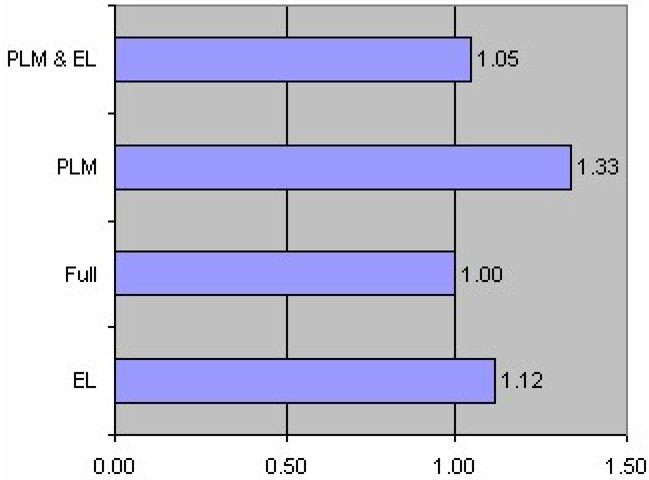


Figure 4.5: The Adjustment Factors for the Speed of Movement regarding Different Lighting Systems.

For the testing of this component, 50 batch runs were carried out for each lighting system using the FEDG evacuation scheme. However, only 1 occupant was considered in these tests so as to examine the efficiency of these adjustment factors without the influence of occupant density (since the occupant density is a crucial factor that affects the total evacuation time). The input codes for these lighting systems in the MAP file are illustrated as follows:

```
<ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
</ConnectionType>
<LightingType>Full</LightingType>
```

Full lighting condition in the stairwell

```
<LightingType>Emergency</LightingType>

<LightingType>Emergency + Photoluminescient</LightingType>

<LightingType>Photoluminescient</LightingType>
```

3 other lighting systems

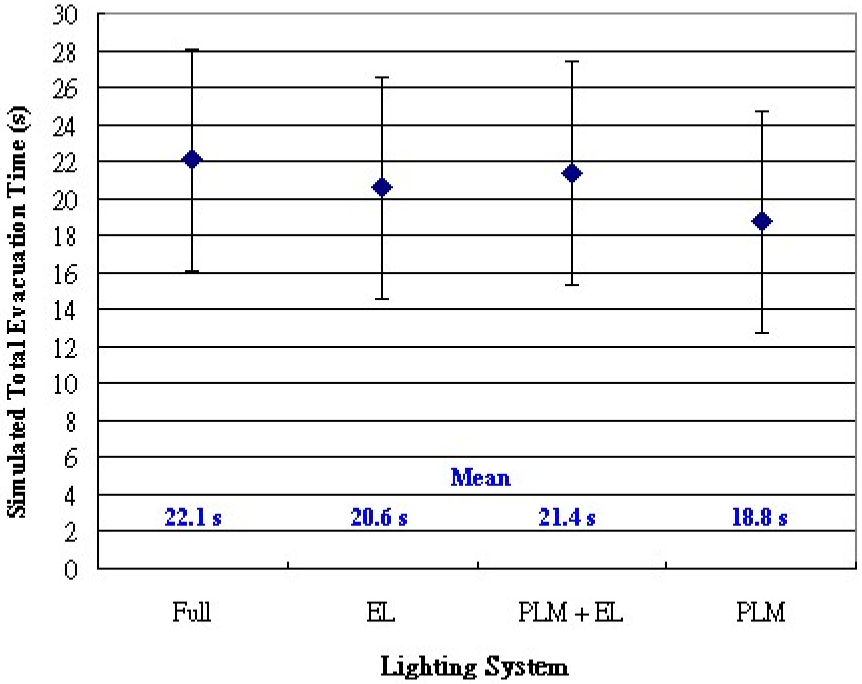


Figure 4.6: The Time required for the Occupant to reach the Exit under Different Lighting Condition in the Stairwells.

The mean and the distributed range of the total time that the occupant evacuated from the room to the exit out of 50 batch runs under the four different lighting conditions are summarized in Figure 4.6. The means generated according to this figure seem to be quite reasonable compared to the adjustment factors indicated in Figure 4.5, for which the movement speed can mostly be affected under the PLM condition and is less likely to be influenced under the combination of PLM and EL. Consequently, the functional integrity of this component is verified for occupants to travel under these four lighting conditions.

It should also be noted that even though the movement speed can be affected by these lighting conditions, more significantly it depends on the density of the existing crowd. This statement is further verified through the sensitivity analyses done in Section 6 of this report, where a large population was involved in a 13-storey office building evacuation.

5.0 Trial Evacuation on a 21-Storey Hotel Building

To ensure life safety in building structures, trial evacuation analyses have become an essential part of fire safety design. Commonly, the egress system designs are carried out using hand calculation methods that follow the equations represented by Nelson et al. (2002). However, for large and complex building structures such as high-rise buildings, the calculations may require considerable efforts in designing several scenarios with iteration procedures. As mentioned previously, Simulex and EXIT89 are the two prominent partial behaviour computer models that efficiently simulate occupants' movement on complex built geometries. Kuligowski et al. (2005) performed some trial evacuations using these two models on a hypothetical 21-storey hotel building, and carried out comparative measures with different documented evacuation movement data. Nevertheless, the design scenarios and the trial evacuation schemes were not interpreted from the real events, and therefore, accuracy was not a dominant issue in those comparisons.

To produce a fundamental review of its functional integrity on high-rise building analysis, similar trial evacuation systems were carried out using EvacuatioNZ. EvacuatioNZ is a coarse network model that can either represent an entire floor as a single node or divide the floor into several small nodes to represent a more detailed floor layout. The comparisons between these two node configurations have not yet been investigated by previous researchers. Also, the input value of the LOD should vary with respect to the amount of disabled people associated with a pre-defined MND. Thus, several sensitivity analyses were carried out to determine the functional integrity of using simple and complex node configurations, and to further identify the optimal MND and LOD values where disabled people are concerned.

5.1 Building Descriptions

The floor plan of the hypothetical 21-storey hotel building is based on a 28-storey hotel building located on the west coast of the United States. The building contains 473 guest rooms that can each accommodate 2 to 5 guests depending on the room size; a 74 m^2 conference room on the first floor; elevators at the building's central core; and two emergency exits on each floor that lead to the right and left stairways. During the simulated trial evacuations, the conference room is assumed to contain no occupants, and the elevators are not functionally operated. Occupants leave their respective floor through the corridor to the stairways, which have an accessible clear width of 1.13 m and 7.2 m in length between each two levels. The detailed geometry layout and the exit locations on each floor are shown in Figure 5.1 and 5.2.

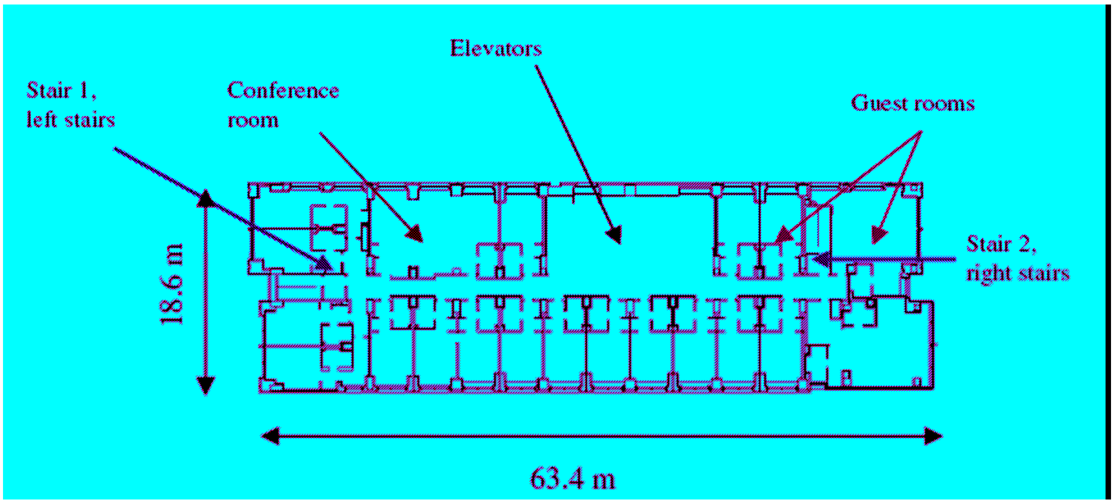


Figure 5.1: The Plan View of the 1st Floor. (Kuligowski et al, 2005)

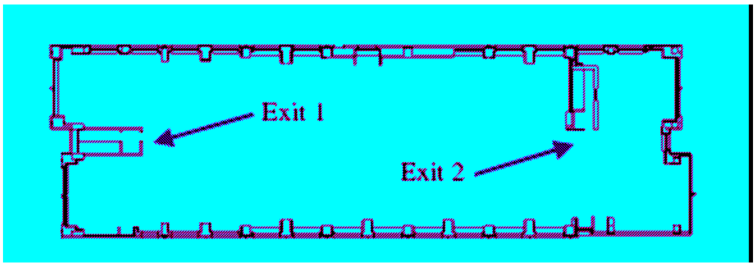


Figure 5.2: The "Safe Node" on the Ground Floor. (Kuligowski et al, 2005)

5.2 Design Scenario

Based on the frequencies of fire causes and origins, Kuligowski et al. (2005) stated that the design scenario relates to the involvement of fire injuries and property losses tabulated in the NFPA US Fire Problem Overview of hotel and motel fire statistics (Ahrens, 2001). The fire statistics show that the fire frequently occurs in the bedroom due to flammable or smoking materials; and when the fire originates on the lower floors occupants can experience higher risk due to the migration of smoke and toxic gases. Thus, in the design scenario the fire is assumed to start in one of the bedrooms on the fifth floor. Nevertheless, as the occupants' conditional behaviours are not considered during the model simulations these presumed fire conditions are not dominant issues that affect the timing of the trial evacuations.

Other conditions that are given more consideration in the design scenario are the event time and event season. To present the worst case scenario, the fire is assumed to occur at 3 a.m. during the winter season. The nighttime scenario assumes that the occupants require more time to wake up from sleep and notice the fire; whereas, the winter scenario assumes that the occupants need additional time to dress appropriately to withstand the cold weather outside the hotel. The functional input of the delay periods is either uniformly distributed between 0.5 min and 10 min (EXIT89), or has a uniformly distributed range of 5 min $\pm$ 5 min (Simulex) as stated in Kuligowski et al, 2005. The two models have different functional input for the pre-movement time, but their generated delay time distributions enclose very similar time ranges. In EvacuatioNZ, the overall occupants delay period is assumed to be uniformly distributed between 0.5 min and 10 min as a reasonable comparative measure.

A total of 1044 occupants are involved in these simulations and occupants are safe once they reach the stair door of the ground floor. These evacuees are assumed to only travel horizontally and downwards with no returns. Due to the fact that this is a hypothetical event, the occupants' movements can only be based on the previous research that related to the observed human behaviours. Realistically, occupants' responses to an emergency event can vary in a significant way due to their different personalities. Therefore, there are no standard data available to precisely imitate occupants' movements in evacuation models.

Furthermore, these occupants are assumed to evacuate through the shortest routes that lead to the nearest exits, which is a frequent egress behaviour in an evacuation system. Once the occupants start to evacuate, they move directly towards the exit door that has the shortest route to safety even when a large existing crowd impedes the occupants flow. Although, in a real event, some of the occupants may want to choose longer pathways that have much less of a queuing effect, these uncertainties are generally ignored when a large population is present due to their minor influence on the total evacuation time.

The amount of disabled occupants involved is also considered as another dominant variable that affects the total evacuation time. In this design scenario, the occupants are assumed to vary in the percentage of disabilities. Three cases are to be examined and compared in both delay and no delay situations: these are 0% disabled, 3% disabled, and 100% disabled. The detail inputs of the occupants' characteristics for this 21-storey hotel building are briefly summarized in the following section.

5.3 Data Inputs/Assumptions

5.3.1 EXIT89

EXIT89 is a coarse network model that is capable of simulating large populations in high-rise building structures. Functionally, the model contains a variety of input features regarding escape route (shortest or user-defined), smoke blockage (imported from CFAST smoke data or none), body sizes (0.1458 m^2 for large, 0.113 m^2 for medium, or 0.0906 m^2 for small), traveling speed (emergency or normal; a function of occupant density), pre-movement time (single value or uniform distribution), and disabled people (user-defined percentage). For the hypothetical 21-storey hotel building, the inputs for the design scenario were tabulated as follows:

Input Type	User Choices/Input		
Building configuration	Node and arc positions	Area of each node (usable space)	Distance from node to node (arc)
Evacuation route	Shortest route chosen for all occupants		
Environment	No smoke blockages		
Behaviour – body size	All 0.113 m^2 (medium body size - Soviet)		
Behaviour – speed (able-bodied)	Emergency speed = 1.36 m/s unimpeded horizontal		
	Emergency speed = 0.99 m/s on stairs		
Uniformly distributed response time	Minimum delay time = 0.5 min	Maximum delay time = 10 min	100% of population to delay
Occupants with disabilities	3 Cases: 0% ; 3% ; 100%		
Stair travel	Downwards		

Table 5.1: Inputs for the Evacuation Design Scenario using EXIT89. (Kuligowski et al, 2005)

Disabled occupants are assumed to travel at 45% of able-bodied speed, where the 45% value was obtained from the research done by Boyce et al. (1999). The detailed characteristics of disabled occupants are not specified in the referenced article, but the body sizes are assumed to stay the same as the able-bodied occupants for all tests.

5.3.2 Simulex (Version 4.0)

Simulex is another prominent evacuation model that can realistically analyze the egress behaviour of large populations under geometrically complex structures. Unlike EXIT89, Simulex is a fine network model that does not involve node/arc geometry set-ups, but rather imports the 2-D floor plans through CAD drawings. Even so, the width and length of the stairways that connect between floors need to be specified by the user. The program is also capable of creating distance maps to simulate several scenarios regarding different exit pathways for groups of occupants.

In terms of occupant characteristics, Simulex has the capability of defining occupant type with respect to their body sizes (males, females, or children, etc.), movement speed horizontally or on stairs (user-defined or default values), and delay times (uniform, triangular, or normal distributions). The detailed inputs for the design scenario of this 21-storey hotel building are summarized as follows:

Input Type	User Choices/Input			
Building configuration	Import CAD file; Stair distance = 7.2 m, width = 1.13 m			
Evacuation route	Shortest route			
Environment	No exit blocked from certain occupants			
Behaviour – body size	49% males (0.131 m^2)	35% female (0.101 m^2)	11% elderly (0.113 m^2)	5% children (0.072 m^2)
Behaviour – unimpeded speeds (able-bodied)	Males (1.35 ± 0.2) m/s	Females (1.15 ± 0.2) m/s	Elders (0.9 ± 0.3) m/s	Children (0.8 ± 0.3) m/s
Response delay	Mean delay time = 300 s; (+ or -) 300 s of time for delay; Uniform distribution			

Table 5.2: Inputs for the Evacuation Design Scenario using Simulex. (Kuligowski et al, 2005)

The percentage distribution of the occupant types were calculated using the information set by D. K. Shifflet's DIRECTIONS Travel Information System and the American Hotel and Lodging Association (cited in Kuligowski et al., 2005).

5.3.3 EvacuatioNZ

Similar to EXIT89, EvacuatioNZ is a coarse network model that represents any building structure with node/arc configurations. The node/arc network is able to generate realistic configurations for compartmented buildings, where the floors are segmented into rooms, corridors, and stairways. Nevertheless, for large and complex building structures, such as this 21-storey hotel building, the user has to make sure that the occupants evacuate in a realistic pattern with the specified segments and links.

As discussed previously, the model incorporates 6 input files that determine the evacuation schemes physically and behaviourally. By comparison with EXIT89 and Simulex, the assumed data inputs using EvacuatioNZ are summarized as follows:

Input Type	User Choices/Input		
Building configuration	Node and arc positions	Area of each node (usable space)	Distance from node to node (arc)
Evacuation route	All occupants choose the nearest exits		
Behaviour – body size	None (not available for the current version)		
Behaviour – location	Occupants are randomly distributed on each floor		
Behaviour – speed	Average emergency horizontal unimpeded speed (constants) = 1.5 m/s for able-bodied; = 0.7 m/s for disabled		
Uniformly distributed response time	Minimum delay time = 0.5 min	Maximum delay time = 10 min	100% of population to delay
Occupants with disabilities	3 Cases: 0% ; 3% ; 100%		

Table 5.3: Inputs for the Evacuation Design Scenario using EvacuatioNZ.

The traveling speeds for able-bodied and disabled occupants are referenced from the research done by Fahy et al. (2001) for hotel purpose structures. It should be noted that even though the speeds are greater than the other two models, it has little impact on the total evacuation time due to the fact that the occupants’ flow is mostly influenced by the density of the existing population.

5.4 Sensitivity Analysis/Results

5.4.1 Complexity of Node Configurations

EvacuatioNZ uses node/arc geometry set-ups with unlimited user-defined domains. Functionally, each floor plan can be rearranged with different node configurations depending on the intention of evacuation schemes. An example is shown in Figure 5.3. The user can either individually define each conference room and each office as a single node that connects to a central foyer when the egress behaviour of the occupants in these rooms are significantly concerned, or the user can model all the conference rooms and offices as single nodes for comparative measures.

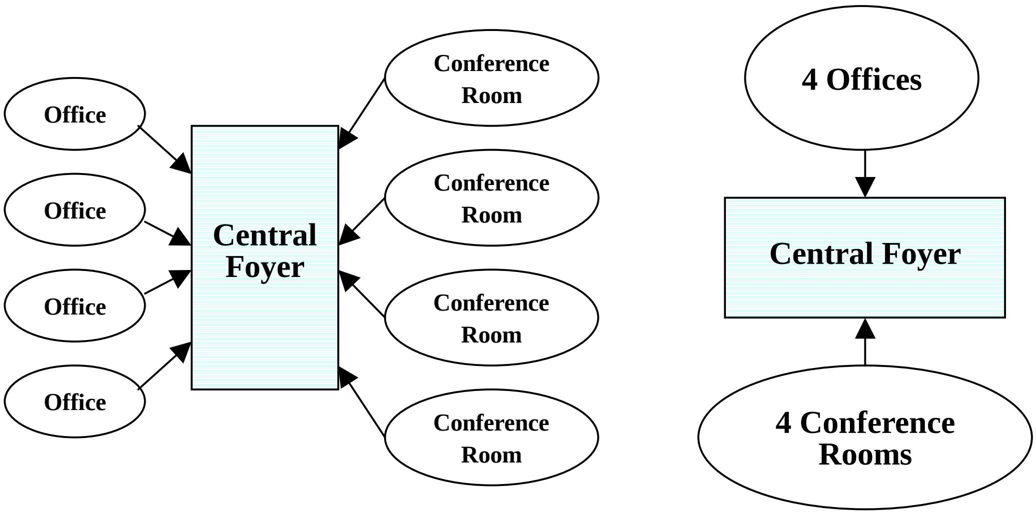


Figure 5.3: An Example of Different Node Configuration Set-ups with the Same Floor Layout.

Nevertheless, there is often a case when the total evacuation time is the only important outcome. For instance, due to complex building structures, such as this 21-storey hotel building, users may require a considerable amount of time setting the model up. Thus, sensitivity analyses were carried out based on the given floor plan (refer to Figure 5.1) to differentiate the functional integrity of the EvacuatioNZ model by using simple and complex node arrangements.

Simple Node Configuration

Each floor is simply represented as a single node, and the stairway that connects every two floors is also represented as a single node.

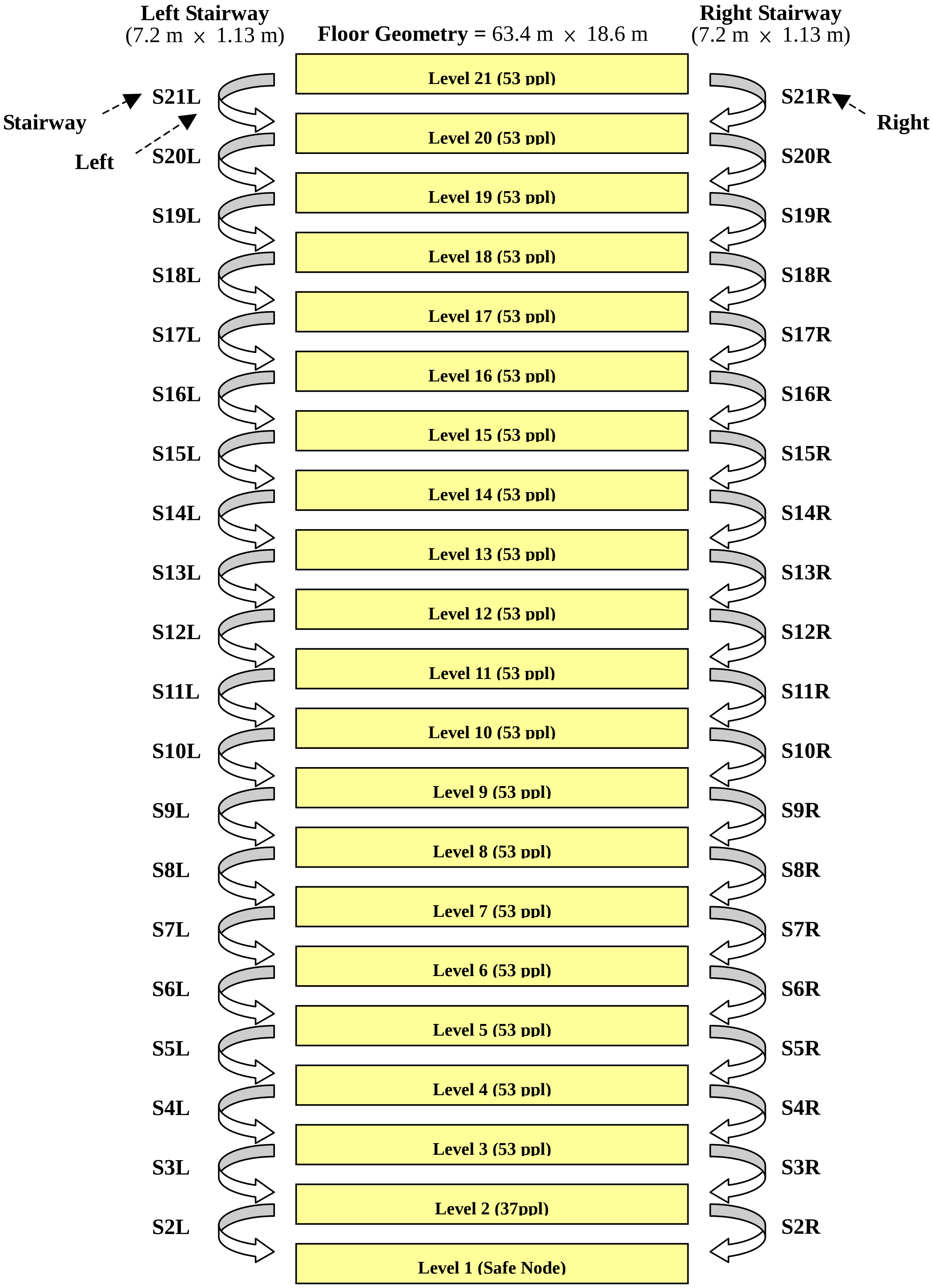


Figure 5.4: Representative Layout of Simple Node Configuration.

Complex Node Configuration

Each room (occupants contained) on each floor is represented as a single node, and the corridor is represented as a single node that connects with those rooms on each floor. The stairway that connects every two floors is also represented as a single node.

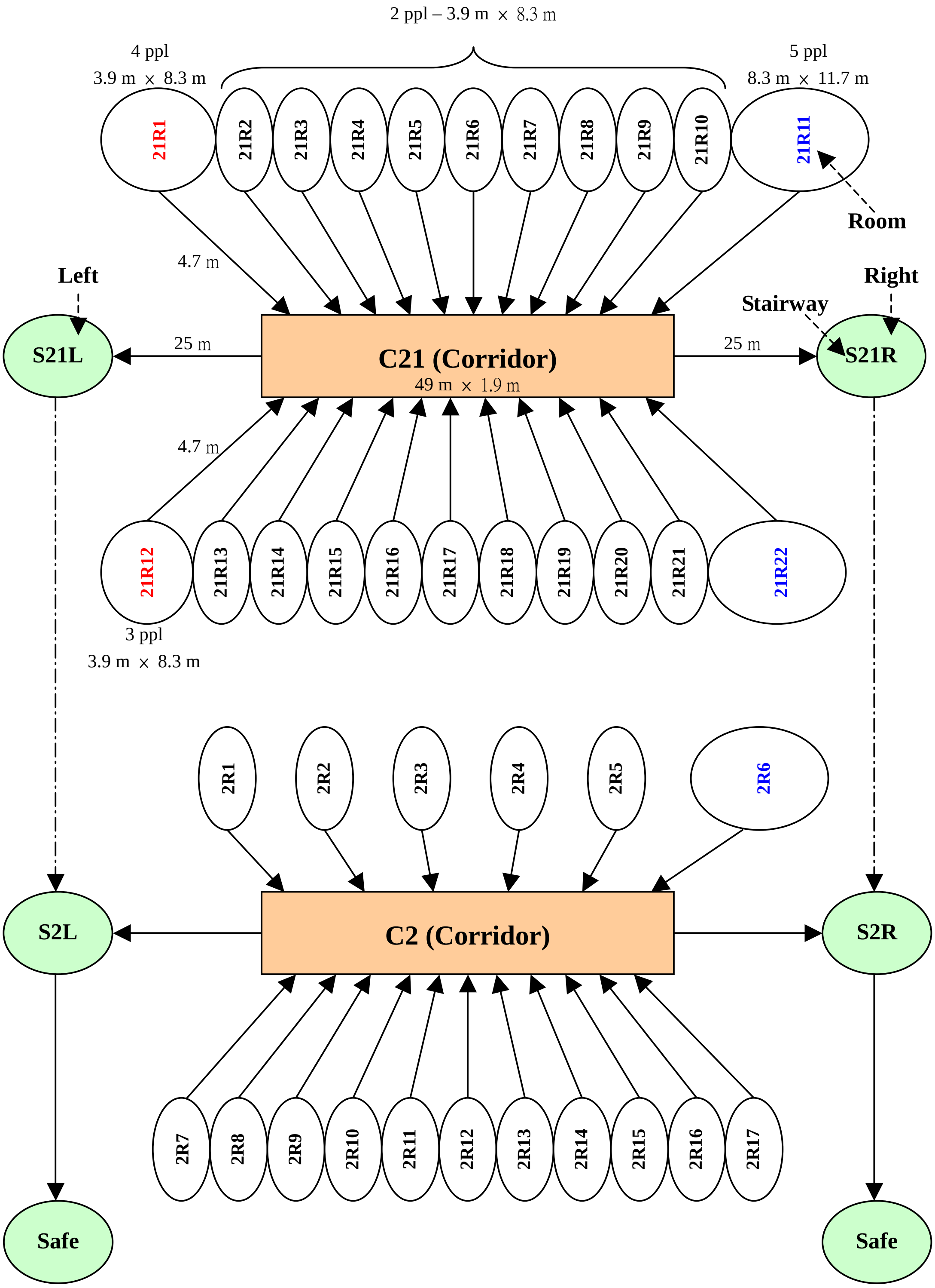


Figure 5.5: Representative Layout of Complex Node Configuration.

The dimension of the rooms, corridors, stairways, and each floor are scaled and extracted from the given floor plan. Also, it is assumed that each floor contains 53 occupants except the first floor (37 occupants) due to the usage of a conference room in that level. As defined previously, occupants are said to be safe once they reach the stair door of the ground floor.

The simple node configuration requires a total of 61 nodes to represent all the 21 floors as well as the connecting stairways, whereas the complex node configuration uses 496 nodes to characterize detailed floor layouts and stairway connections. The detailed construction of building layouts can not only lead to the consumption of modeling time, but also can introduce a higher possibility of inputting errors.

Also, the defined number of occupants is assumed to randomly distribute over all the floors when the simple node configuration is used and as specified in the SCENARIO file and POPULATE file. The modeling input is quite straightforward. Conversely, complex node configuration utilizes more computational effort to functionally input all the occupants into their respective rooms on each floor. Refer to Appendix B for the examples of 6 input files using simple and complex node configurations.

Before testing these two different node arrangements, the optimal input values for the maximum node density and local occupant density with the involvement of disabled occupants should be identified in order to obtain sensible results for comparative measures. In this context a sensible result is chosen based on the comparison of other models' results between each test. Hence, a further discussion on the comparison of these two node configurations is associated with the determination of the optimal MND and LOD values, which are represented in the next section.

5.4.2 Optimal MND and LOD Input Values for Disabled Occupants

Unlike EXIT89 and Simulex, the current version of EvacuatioNZ cannot model body sizes with different types of occupancies, but rather uses the input functions of MND and LOD to represent the level of crowdedness among the involved occupants.

Nelson et al. (2002) stated that the maximum occupant density has a suggested value of 3.8 ppl/m^2. No movement will take place when the occupant density exceeds this limit unless the crowd has reduced its density by passing through the crowded area. Pauls (1995) also mentioned that an occupant density of 3.5 ppl/m^2 can hardly be achieved in reality. Therefore, it is assumed that 3.5 ppl/m^2 is the highest possible occupant density allowed in each node.

Further, Teo (2001) found that a LOD of 2.2 ppl/m^2 can give the best results and matches well with the Nelson and MacLennan flow correlations between different door widths for able-bodied occupants (0% disabled). With the intention of obtaining the optimal combinations that give most sensible results, an initial analytical approach was carried out in situations when there were no disabled occupants involved in order to find the recommended MND. By applying the recommended MND, the LOD was then used as a variable to account for the inclusion of either 3% or 100% disabled of the egress population. The preliminary combinations of MND and LOD with 0% disabled are shown in the table below.

Combination No.	MND	LOD
#1	3.5 ppl/m^2	2.2 ppl/m^2
#2	3.0 ppl/m^2	2.2 ppl/m^2
#3	2.5 ppl/m^2	2.2 ppl/m^2

Table 5.4: The Combinations of MND and LOD for the Involvement of 0% Disabled.

For each of the combinations, 100 batch runs were performed to get an average value for comparison to the results obtained by EXIT89 and Simulex. Once the optimal combinations of MND and LOD were identified for different percentages of disabled occupants, the geometry set-ups began with simple node configuration and the simulation outcomes were compared with the results obtained using complex node configuration. From the combinations specified in Table 5.4, the comparison of the simulation results using the 3 models were compared in delay and no delay situations for the scenario of 0% disabled and are presented in Table 5.5.

Total Evacuation Times (0% Disabled)		No Delay		Delay	
EXIT89		**445 s**		**809 s**	
Simulex		**698 s**		**1091 s**	
EvacuatioNZ	**Combination #1**	1107 s (min)	**395 s**	970 s (min)	**418 s**
		1232 s		**1156 s**	
		1502 s (max)		1388 s (max)	
	Combination #2	636 s (min)	**58 s**	783 s (min)	**72 s**
		659 s		**806 s**	
		694 s (max)		855 s (max)	
	Combination #3	529 s (min)	**24 s**	775 s (min)	**49 s**
		539 s		**796 s**	
		553 s (max)		824 s (max)	

Table 5.5: The Comparison of the Simulation Results for the 3 Models with 0% Disabled.

When compared to EXIT89, Kuligowski et al. (2005) concluded that Simulex can generally provide a 25-40% higher evacuation time due to the differences in a number of functional features. These include the movement algorithm (i.e. EXIT89 simulates occupants to have higher unimpeded speed on horizontal components and stairs), the number of occupants allowed at a time in the stairs (i.e. EXIT89 allows more occupants to gather in the stair section at one time), and the way of predicting slower occupants (i.e. EXIT89 does not take account of occupant interference). Even though the accuracy of the simulation results for these two models could not be ascertained as the evacuation schemes were hypothetical events, these predicted total evacuation times provide useful information on the determination of the optimal MND and LOD combinations with respect to the amount of disabled occupants involved.

As shown in Table 5.5, when using Combination #1 the average total evacuation time in the no delay situation simulated is longer than that in the in delay situation, which seems to be improbable compared to the results obtained by EXIT89 and Simulex; whereas, Combinations #2 and #3 appear to provide more sensible results both in delay and no delay situations. By looking further into the simulation outcomes, EvacuatioNZ appears to generate similar results to EXIT89 in delay situations for both Combinations #2 and #3. The tested MND of 3.0 ppl/m^2 and 2.5 ppl/m^2 can only have substantial impact on the time difference in no delay situations where the occupants move towards the exits at the same time with different queuing effects. As a consequence, two cases were carried out with the involvement of disabled occupants using the MND specified in Combinations #2 and #3 for further sensitivity analysis:

- Case 1: MND = 3.0 ppl/m^2 LOD = 2.2 ppl/m^2 (for 0% disabled)
- Case 2: MND = 2.5 ppl/m^2 LOD = 2.2 ppl/m^2 (for 0% disabled)

It can also be noted that as the value of the MND increases, the distribution range of the simulation results becomes wider (as indicated in Table 5.5). This is because the occupant walking speed or the occupant flow is influenced by the density of the exiting crowd. Also, due to the fact that the occupants were randomly distributed over the floors, occupant movements would have more chance to be impeded by having higher occupant density allowed in that node; thus creating the wider range of total evacuation times.

Case 1 (MND = 3.0 ppl/m^2)

To account for disabled occupants when using the EvacuatioNZ model, the LOD may need to be reduced as the occupants may carry traveling devices (e.g. wheelchair) that occupy larger areas. In this case, the MND is considered as a constant and the LOD shall behave as a variable with respect to the percentage of disables involved. For both scenarios concerning 3% and 100% disabled, the values of the three different LODs that were tested are shown in Table 5.6.

Combination No.	MND	LOD
#4	3.0 ppl/m^2	2.0 ppl/m^2
#5	3.0 ppl/m^2	1.5 ppl/m^2
#6	3.0 ppl/m^2	1.0 ppl/m^2

Table 5.6: The Combinations of MND and LOD for the Involvement of 3% and 100% Disabled.

Similarly, as shown in Table 5.6, 100 batch runs were carried out for each of the combinations. The simulation results and the model comparisons for the condition of 3% disabled are tabulated as follows:

Total Evacuation Times (3% Disabled)		No Delay	Delay
EXIT89		633 s	969 s
Simulex		1079 s	1264 s
EvacuatioNZ	Combination #2	659 s	806 s
	Combination #4 (no significant change in body sizes)	640 s (min)	794 s (min)
		665 s	851 s
		713 s (max)	993 s (max)
	Combination #5	673 s (min)	845 s (min)
		1240s	1193 s
		1393 s (max)	1430 s (max)
	Combination #6	1956 s (min)	1847 s (min)
		2032 s	2001 s
		2097 s (max)	2122 s (max)

Table 5.7: The Comparison of the Simulation Results for the 3 Models with 3% Disabled.

For EvacuatioNZ to simulate 3% disabled with no delay, the assumed LOD of 2.0 ppl/m^2 (Combination #4) seems to give the best approximation when compared to the results obtained by EXIT89 and Simulex. However, in the delay situation, this assumed LOD did not give comparable times with the other two models. But rather, the assumed LOD of 1.5 ppl/m^2 gave a well covered range of total evacuation times simulated by the other two models. From the results shown in Table 5.7, a number of issues proved that the MND of 3.0 ppl/m^2 may not be an ideal assumption to account for 3% disabled. These issues are briefly discussed as follows:

- The optimal value of the LOD should be consistent in delay and no delay situations because the same amount of disabled occupants were considered in both scenarios. However, in this case the optimal LOD for “No Delay” and “Delay” were 2.0 ppl/m^2 and 1.5 ppl/m^2, respectively.

- For Combinations #5 and #6, the average total evacuation times in the no delay situation were higher than in the delay situation. In contrast to the times simulated by EXIT89 and Simulex this finding appears to be inappropriate.

- Unlike EXIT89 and Simulex, the simulation results using Combination #4 (3% disabled) seem to have little difference when comparing to the times obtained using Combination #2 (0% disabled). This might also be due to the fact that the occupant body sizes were similar in both cases. If the local door queue density was not significantly changed to account for those people with disabilities, numerically it seems 3% of disabled would not have much impact on the total evacuation time. This also verifies that in EvacuatioNZ modeling not only the occupants walking speed needs to be reduced, but also the density of the local occupants should be considered in order to generate more realistic results.

For 3.0 ppl/m^2 MND, similar procedures were carried out when all the people were assumed as disabled occupants using simple node configuration. The simulation results using the combinations stated in Table 5.6 are shown in the table below.

Total Evacuation Times (100% Disabled)		No Delay	Delay
EXIT89		**990 s**	**1226 s**
Simulex		**1230 s**	**1647 s**
EvacuatioNZ	**Combination #2**	**659 s**	**806 s**
	Combination #4 (No significant change in body sizes)	663 s (min)	885 s (min)
		878 s	**984 s**
		1074 s (max)	1117 s (max)
	Combination #5	1342 s (min)	1370 s (min)
		1390 s	**1448 s**
		1430 s (max)	1529 s (max)
	Combination #6	2068 s (min)	2105 s (min)
		2097 s	**2165 s**
		2141 s (max)	2243 s (max)

Table 5.8: The Comparison of the Simulation Results for the 3 Models with 100% Disabled.

From the results shown in Table 5.8, there are two issues that point out the inappropriate usage of MND as 3.0 ppl/m^2 for 100% disabled:

- Similar to the results obtained in 3% disabled, the optimal LOD seems to be inconsistent in the delay and no delay situations when there were the same amount of disabled occupants. (2.0 ppl/m^2 in “No Delay”, 1.5 ppl/m^2 in “Delay”)

- The optimal LODs in the delay and no delay situations were the same for both 3% and 100% disabled. This is not sensible as the amount of disabled occupants increases the local occupant density queuing at doorways should become much smaller (considering disabled occupants generally occupy larger space than able-bodied occupants) especially from 3% disabled to 100% disabled.

Case 2 (MND = 2.5 ppl/m^2)

In this case, the MND of 2.5 ppl/m^2 was considered as a constant for both 3% and 100% disabled, whereas the LOD should have its variations identical to Case 1 for further sensitivity analysis. Likewise, 100 batch runs were carried out for each of the combinations specified in Table 5.9 in delay and no delay situations. As previously mentioned, the LOD of 2.0 ppl/m^2 (which is similar to the LOD in 0% disabled) is purposely assumed in order to verify whether the total evacuation time for the involvement of disabled occupants is only correlated to the occupant traveling speed, or if it is also interrelated to the LOD function in EvacutioNZ modeling.

Combination No.	MND	LOD
#7	2.5 ppl/m^2	2.0 ppl/m^2
#8	2.5 ppl/m^2	1.5 ppl/m^2
#9	2.5 ppl/m^2	1.0 ppl/m^2

Table 5.9: The Combinations of MND and LOD for the Involvement of 3% and 100% Disabled.

Total Evacuation Times (3% Disabled)		No Delay	Delay
EXIT89		633 s	969 s
Simulex		1079 s	1264 s
EvacuatioNZ	Combination #3	539 s	796 s
	Combination #7 (No significant change in body sizes)	528 s (min)	781 s (min)
		549 s	824 s
		691 s (max)	921 s (max)
	Combination #8	825 s (min)	823 s (min)
		873 s	960 s
		909 s (max)	1023 s (max)
	Combination #9	1300 s (min)	1339 s (min)
		1328 s	1391 s
		1350 s (max)	1471 s (max)

Table 5.10: The Comparison of the Simulation Results for the 3 Models with 3% Disabled.

Table 5.10 shows the simulation results of the total evacuation times for Combinations #7, #8, and #9 with 3% disabled. Looking at the simulated results using Combination #7, there was little difference with the times obtained using Combination #3. When compared to the results obtained by EXIT89 and Simulex for 0% and 3% disabled this phenomenon is not logical because those two models have their time difference of at least 150 s when 3% disabled occupants were involved both in delay and no delay situations. Further, when compared to EXIT89 and Simulex the use of 1.5 ppl/m^2 LOD (Combination #8) seems to give more sensible results; whereas, 1.0 ppl/m^2 LOD appears to give incomparable results that over predict the total evacuation times. Thus, this implies that when using the EvacuatioNZ model the reduction of LOD is essential when disabled occupants are considered in an evacuation scheme. Further sensitivity analyses were performed with 100% disabled using the combinations specified in Table 5.9, where the simulation results and the model comparisons are clearly shown in Table 5.11.

Total Evacuation Times (100% Disabled)		**No Delay**	**Delay**
EXIT89		**990 s**	**1226 s**
Simulex		**1230 s**	**1647 s**
EvacuatioNZ	**Combination #3**	**539 s**	**796 s**
	Combination #7 (No significant change in body sizes)	684 s (min)	878 s (min)
		711 s	**909 s**
		728 s (max)	937 s (max)
	Combination #8	917 s (min)	1046 s (min)
		934 s	**1073 s**
		955 s (max)	1113 s (max)
	Combination #9	1360 s (min)	1462 s (min)
		1376 s	**1500 s**
		1403 s (max)	1548 s (max)

Table 5.11: The Comparison of the Simulation Results for the 3 Models with 100% Disabled.

As it is shown in Table 5.11, Combination #9 seems to give sensible results when compared to the other two models and particularly in the delay situation. It may seem to slightly over predict the total evacuation times using 1.0 ppl/m^2 LOD in the no delay situation, but the results can be conservative for engineering design especially when there are large uncertainties in the disabled occupants' characteristics.

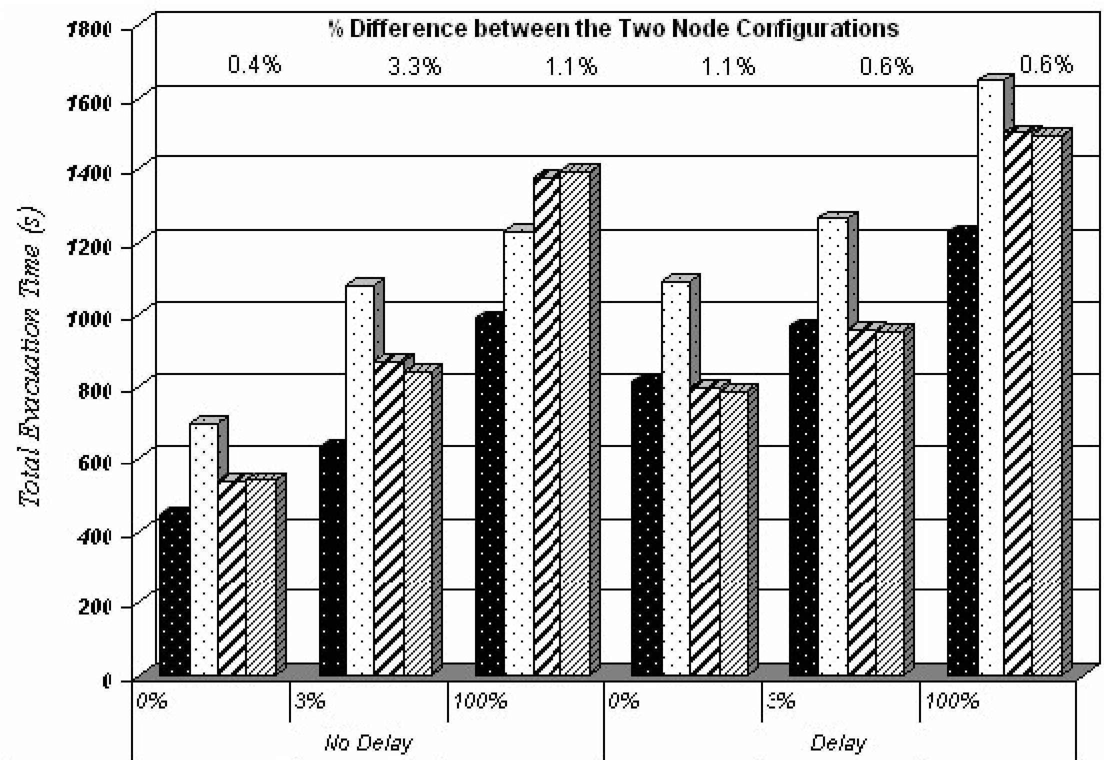
Once again, the total evacuation times obtained using Combination #7 cannot give sensible results when compared to EXIT89 and Simulex. Therefore, to account for the percentage of disabled occupants involved it can be assumed that both the occupant walking speed and the LOD are influential functions in EvacuatioNZ. The following is a general guideline of optimal MND and LOD combinations for future EvacuatioNZ model users to account for different percentage disabled:

- ✓ MND = 2.5 ppl/m^2 LOD = 2.2 ppl/m^2 (0% Disabled)
- ✓ MND = 2.5 ppl/m^2 LOD = 1.5 ppl/m^2 (small% Disabled)
- ✓ MND = 2.5 ppl/m^2 LOD = 1.0 ppl/m^2 (100% Disabled)

It should also be noted that not only does the suggested LOD of 2.2 ppl/m^2 work reasonably well in the situations when there are no disabled occupants present, but it further verifies the functional integrity of the door queuing effect that had been studied by Teo (2001) for able-bodied occupants. On the other hand, further verifications should also be carried out for those optimal combinations that account for small percentage and 100% disabled. Nevertheless, it is hardly likely to have a situation that all occupants are disabled, and therefore, it is not a major concern in this research. Two real data sets have been found to use as further verifications on the involvement of small percentage disabled, which are briefly discussed in Chapter 6 and 7.

Complex Node Configuration Sensitivity Analysis

Further sensitivity analyses were performed to observe the differential effect of simulating simple and complex node configurations for the EvacuatioNZ model. These required some changes in the MAP and POPULATE files, where the complex node configuration was used instead of using the simple one, and the occupants were distributed to each room according to the room size. Also, the optimal combinations of the MND and LOD that were found in the previous section were applied to account for different percentage of disabled occupants involved. Overall, there were 6 different scenarios present with respect to the % disabled (0%, 3% and 100%) and the pre-movement conditions (delay or no delay).



	No Delay 0%	No Delay 3%	No Delay 100%	Delay 0%	Delay 3%	Delay 100%
EXIT89	445	633	990	809	969	1226
Simulex	698	1079	1230	1091	1264	1647
Simple	539	869	1376	796	960	1500
Complex	541	840	1392	787	954	1491

Figure 5.6: The Comparison of the Simulation Results using Simple and Complex Node Configurations.

Correspondingly, 100 batch runs were performed in each of the scenarios using complex node configuration. For comparisons to the EXIT89, Simulex, and particularly to the mean results obtained using simple node configuration, the mean values of the simulated results in each scenario are tabulated in Figure 5.6. From the comparison of the 3 models' results, EvacuatioNZ seems to give sensible predictions on the total evacuation time in this 21-storey hotel building. Even though the simulation data is not based on a real event and the accuracy cannot be assured, some degree of confidence has been demonstrated for the utilization of the EvacuatioNZ model in high-rise building analysis.

Furthermore and as shown in Figure 5.6, the percentage difference of the mean results between simple and complex node configurations are relatively small. Figure 5.7 to Figure 5.12 also represent detailed comparisons of the simulated results, where the mode and the distributed range in each 100 batch runs are clearly shown in the distributions. These comparisons indicate that even though the shape of the distributed results may not have a perfect match between these two node configurations, the generated means and the distributed ranges are still comparable to each other. Consequently, the total evacuation time is not significantly affected by the complexity of the node arrangement within the EvacuatioNZ model. Using simple geometry set-up is adequate enough to generate satisfactory results either with sufficient batch runs (i.e. more than 50 batch runs to be ideal), or otherwise the designer is able to make a desired range of confidence interval that covers the uncertainties.

On the other hand, it may be worthwhile to look at how the number of people exiting with respect to time using these two node configurations, for which the comparisons are basically shown from Figure 5.13 to Figure 5.15 for different scenarios. The results shown in these figures are extracted from the simulations (out of 100 batch runs) that have their total evacuation time identical to the mean result shown in Figure 5.6. As shown in these figures, the complexity of the node configuration does not have a significant effect on the occupants' flow regardless of the delay situation and the amount of disabled occupants involved.

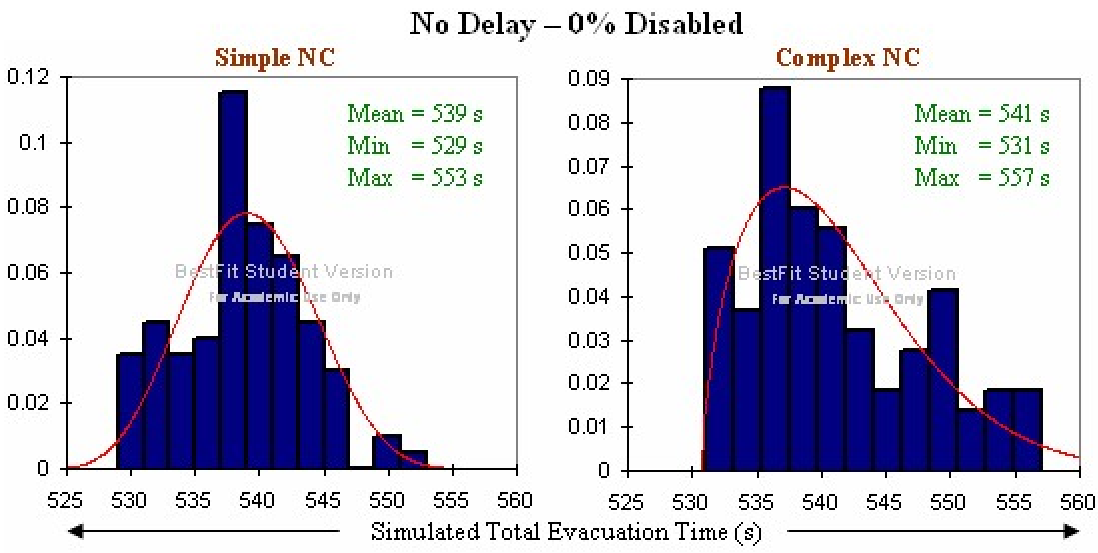


Figure 5.7: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 0% Disabled Occupants Involved in No Delay Situation.

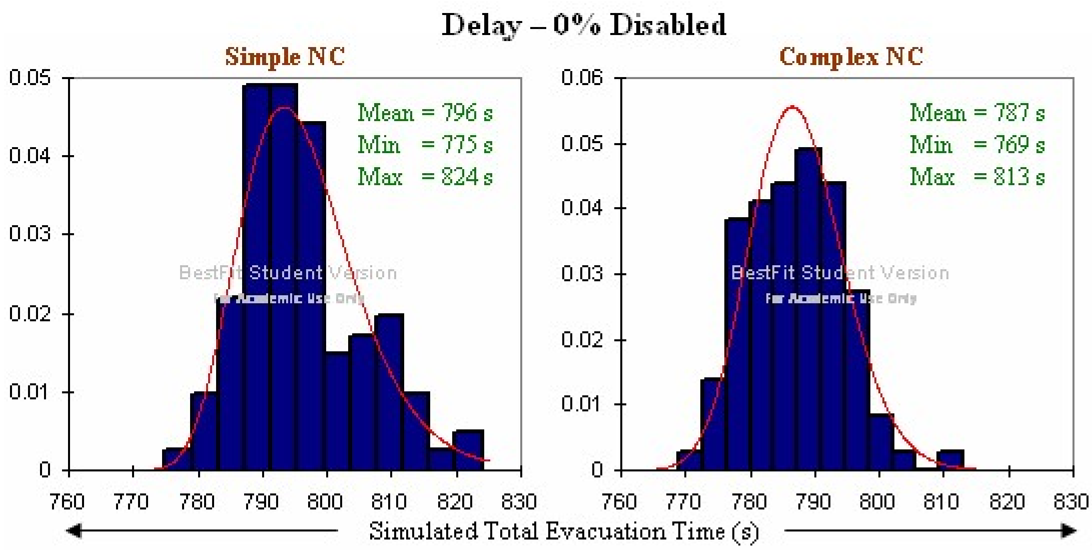


Figure 5.8: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 0% Disabled Occupants Involved in Delay Situation.

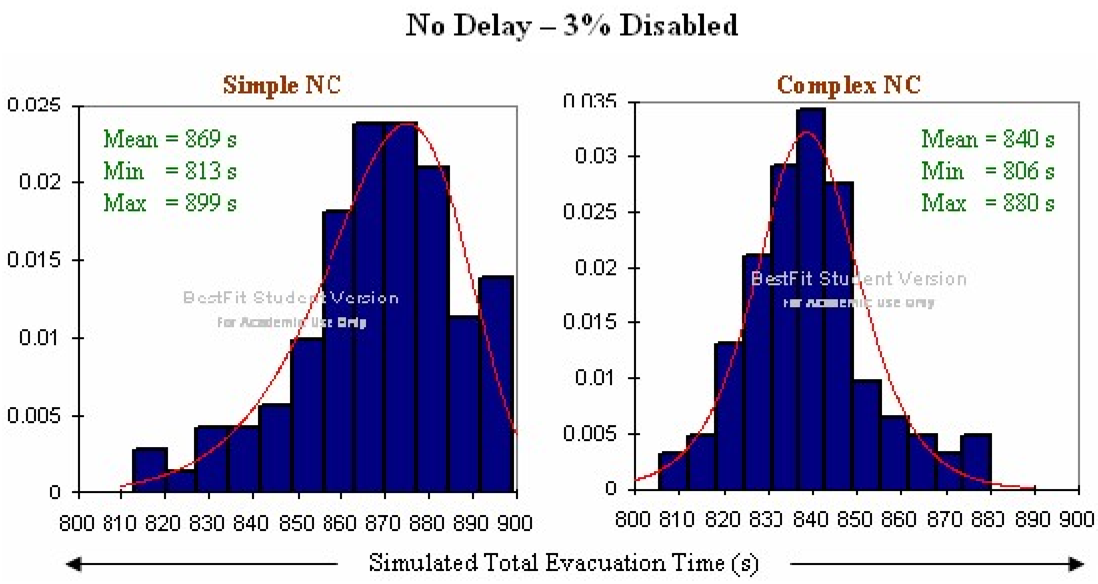


Figure 5.9: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 3% Disabled Occupants Involved in No Delay Situation.

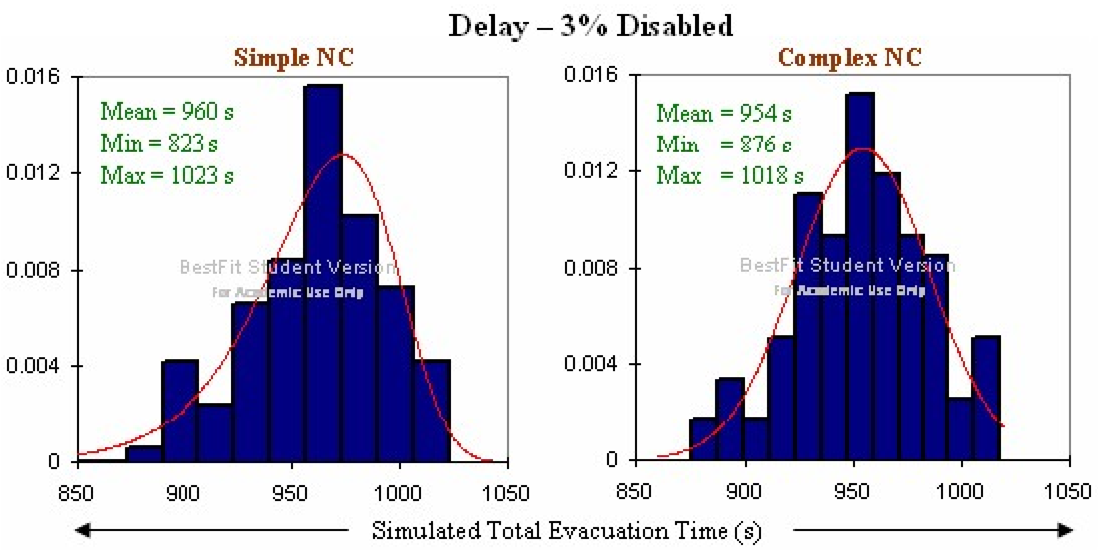


Figure 5.10: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 3% Disabled Occupants Involved in Delay Situation.

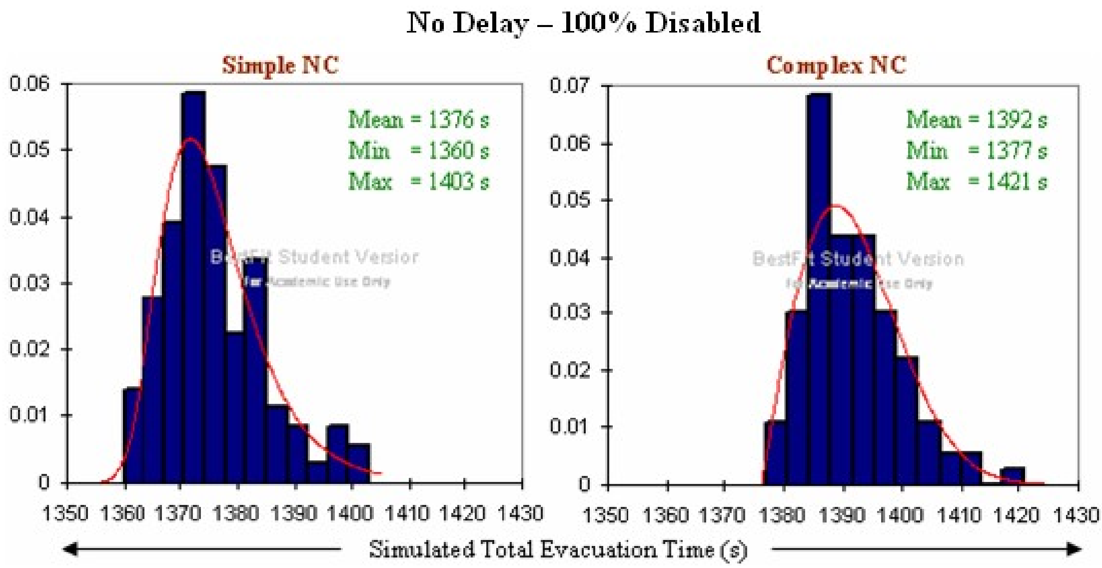


Figure 5.11: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 100% Disabled Occupants Involved in No Delay Situation.

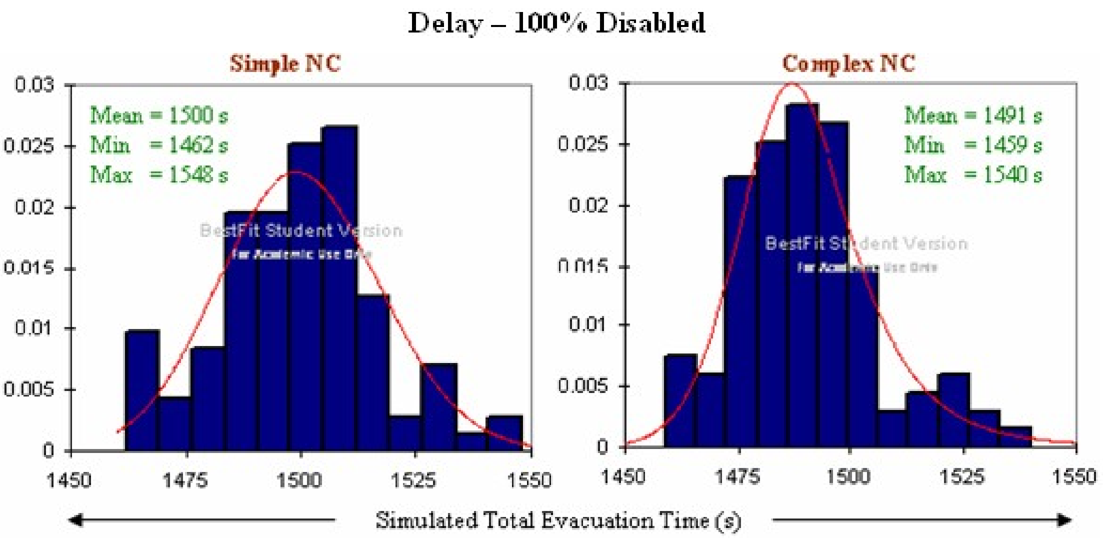


Figure 5.12: The Comparisons of the Total Evacuation Times using Simple and Complex Node Configurations when 100% Disabled Occupants Involved in Delay Situation.

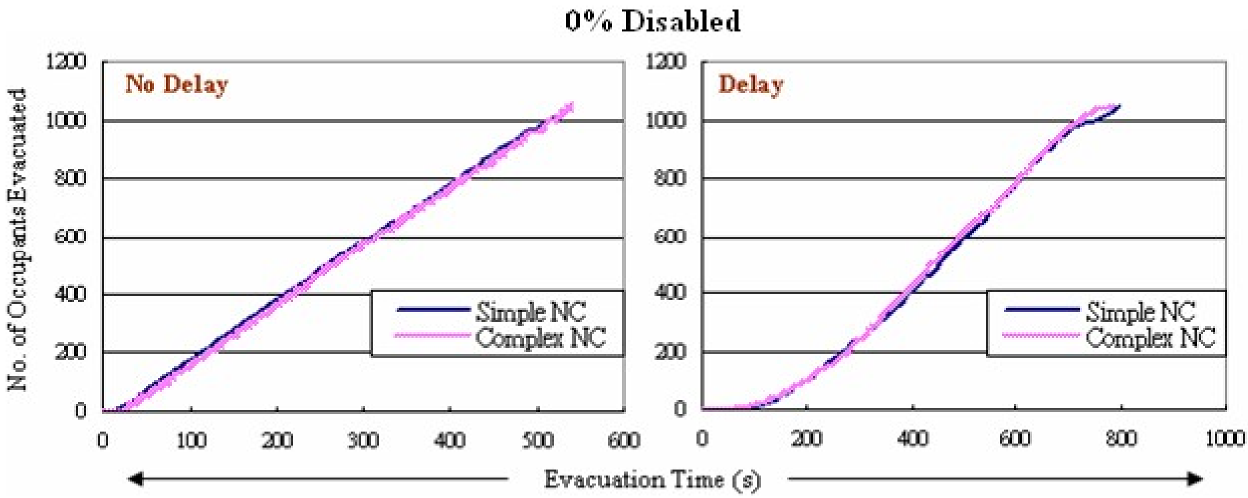


Figure 5.13: The Number of Occupants Exiting with respect to Time with 0% Disabled.

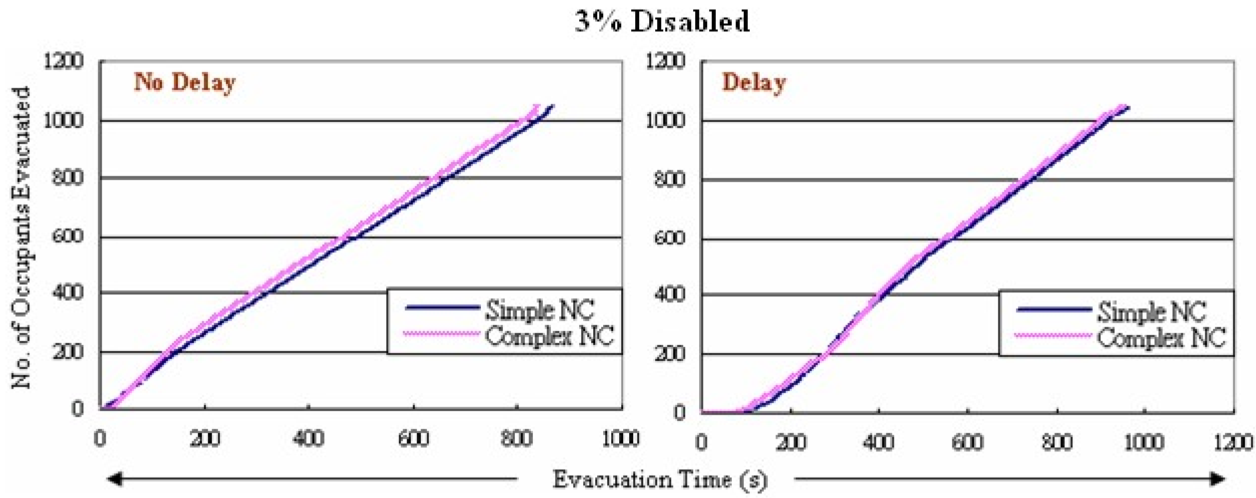


Figure 5.14: The Number of Occupants Exiting with respect to Time with 3% Disabled.

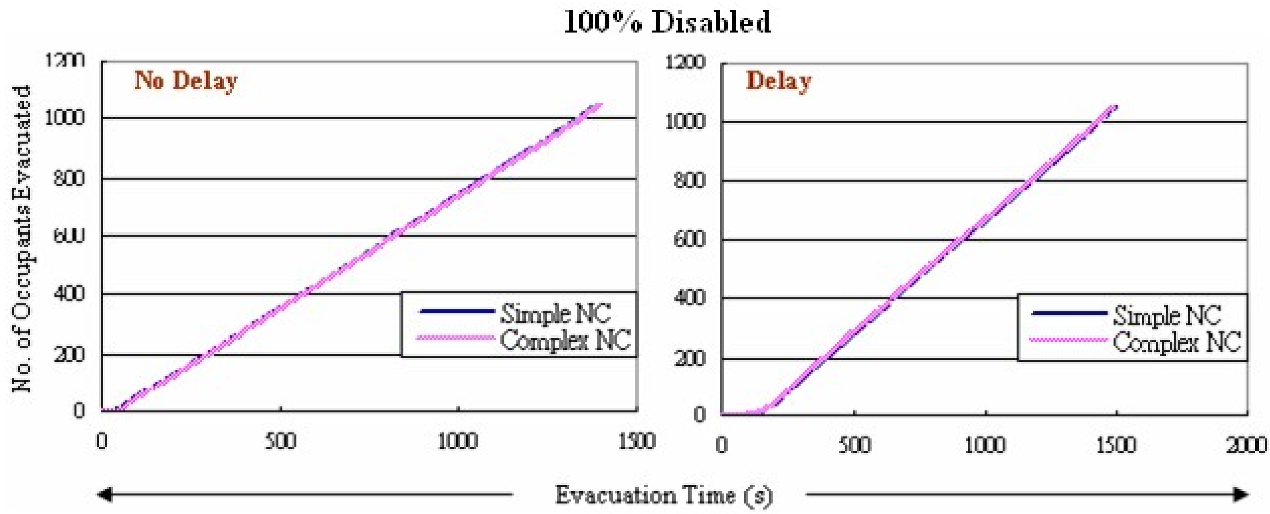


Figure 5.15: The Number of Occupants Exiting with respect to Time with 100% Disabled.

5.5 Conclusions

EXIT89 and Simulex both modeled disabled occupants to have medium body sizes, which were the same as the able-bodied occupants. They did not consider the fact that these disabled people may occupy larger areas causing reduced local occupant density, but rather reduced the unimpeded traveling speed only. Nevertheless, from the simulation results it was shown that EvacuatioNZ could not give satisfactory results if the disabled occupants were only modeled with reduced speed. This may be due to the fact that EvacuatioNZ has different functional properties from EXIT89 and Simulex for the way that it models slower occupants as well as the body size effect. Conservatively, it is recommended for EvacuatioNZ model users to take account of the local occupant density for the involvement of disabled occupants in order to get more realistic results. The optimal combinations of the MND and LOD with different percentage disabled using EvacuatioNZ are summarized as follows:

- ✓ MND = 2.5 ppl/m^2 LOD = 2.2 ppl/m^2 (0% Disabled)
- ✓ MND = 2.5 ppl/m^2 LOD = 1.5 ppl/m^2 (small% Disabled)
- ✓ MND = 2.5 ppl/m^2 LOD = 1.0 ppl/m^2 (100% Disabled)

Furthermore, EvacuatioNZ has the benefits of using simple node configuration for complex geometry layout, particularly in high-rise building analysis. Not only can the user minimize the computational effort and reduce possible input errors, the accuracy can also remain with sufficient batch runs. Overall, EvacuatioNZ seems to generate sensible predictions on the total evacuation time for high-rise buildings while compared to the results simulated by EXIT89 and Simulex. Even though the evacuation scenarios were hypothetical events and no accuracy could be measured for these three models, the comparisons have indicated that the results simulated by the

EvacuatioNZ model were sort of in-between or relatively close to the results simulated by EXIT89 and Simulex. However, in order to further validate the model's functional integrity on high-rise building analysis and to also verify the findings of the optimal MND and LOD combinations, a number of examinations still need to be carried out based on real sets of data.

Due to the limited source and difficultness of performing a full high-rise building evacuation scheme, a complete data entry could hardly be obtained to look at the distribution of evacuation times at different time intervals or matching the EvacuatioNZ results to see how long the occupants can spend at each point in different time frame so as to perform FED analysis in real life situation. Therefore, the emphasis of the validation exercises in this chapter and the following two chapters are solely based on the total evacuation times that are obtained from the limited source data. These validation exercises are only used for preliminary checkpoints to understand how EvacuatioNZ model can perform in high-rise building analysis incorporating with some of the modeling input functions. A complete validation exercise can be carried out at later stage once the model is fully developed with a complete high-rise building evacuation data.

6.0 Trial Evacuation on a 13-Storey Office Building

Proulx et al. (1999) performed a trial evacuation on a 13-storey office building to assess the effect on occupants egress behaviours using different lighting conditions in the stairwells. It was noted through their experiments that for crowd movement the occupants' travel was not significantly influenced by the lighting conditions, but rather depended on the density of the exiting occupants. This statement is further examined using the EvacuatioNZ model, where the lighting system in each stairwell was incorporated with the findings in the referenced report.

GridFlow is partly involved as a comparative model in this evacuation scheme so as to obtain a preliminary understanding of how EvacuatioNZ model works inclusive of pre-evacuation time both comparing to the real data. Some elemental analyses and comparisons were carried out when the occupants in both models were assumed to have normal pre-movement time distribution while the same mean and standard deviation were applied.

The analyses performed for this 13-storey office building also has its focus on the verification of previous findings, such as the optimal combination of MND and LOD, and the use of simple node configuration. Even though only the occupants on 3 floors were evacuated during the experiment, the evacuation data can be used to examine the functional integrity of EvacuatioNZ when there are a limited number of floors involved in a high-rise building evacuation process. The building descriptions, occupant characteristics, evacuation scheme, modeling set-ups and the analytical results are briefly discussed in the following sections.

6.1 Building Descriptions

The 13-storey office building (Jean Talon Building) is located at Tunney's Pasture in Ottawa and is a concrete structure that was built in 1979. The building has an approximate square geometry with its complex floor layout shown in Figure 6.1. Each floor has the dimension of 65 m by 57 m ($\approx$3700 m^2 area), and is divided into four work stations A, B, C and D. Each work station is associated with a stairwell located at the corners of the building. The stairwells have a clear width of 1.1 m and a length of 9.7 m between every two floors. There were two evacuation chairs prepared in Stairwell D for assisting occupants with movement disabilities in their descent to the ground floor. Practically, the studied floors (floors 9, 10 and 11) have similar plan layouts with partition wall arrangements.

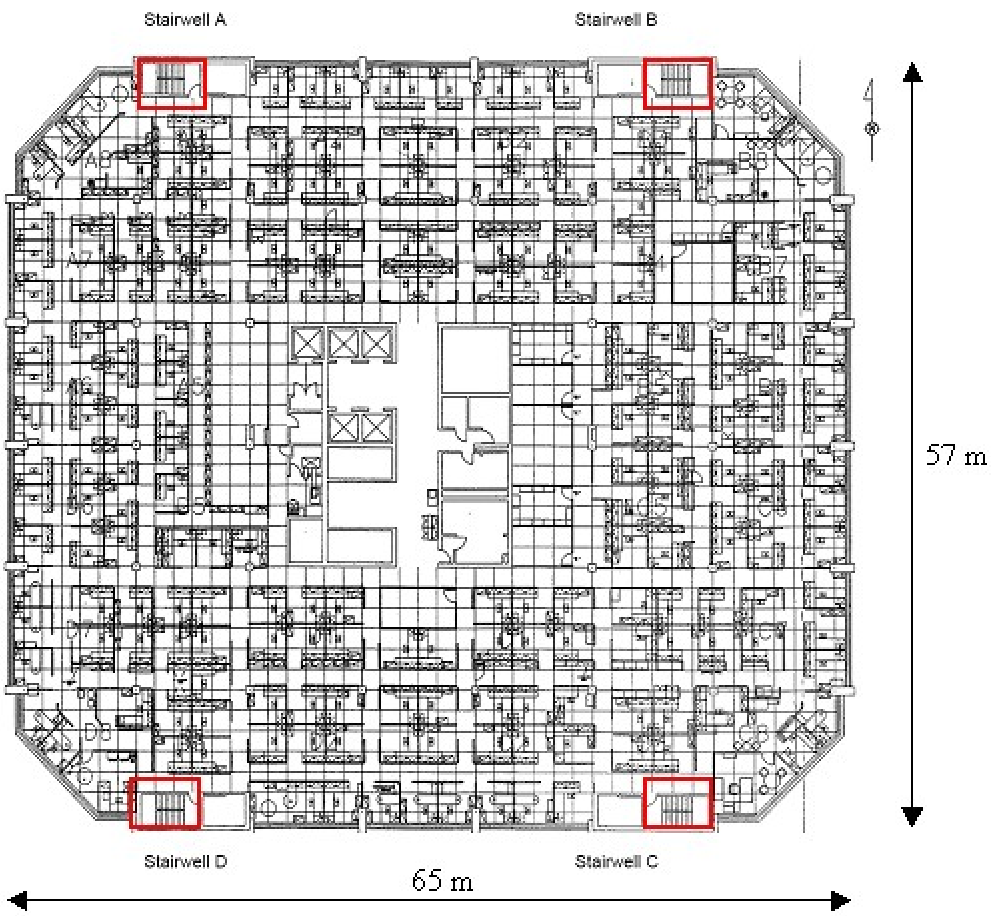


Figure 6.1: The Typical Floor Plan of the Jean Talon Building. (Proulx et al, 1999)

6.2 Evacuees

Even though there were video settings placed around the stairwells and the exit doors, the detailed characteristics of the evacuees could not be accurately defined. The data inputs of the occupants' behaviours could only be estimated through the questionnaires that were completed by most of the evacuees after the trial evacuation. Overall, there were 457 occupants involved in the drill with a number of occupants who were unable to leave their respective floors due to unspecified reasons. A total of 392 occupants were caught in the videos who actually used the stairwells during the evacuation (approximately 131 office workers in each floor). These occupants were said to be safe once they reached the exit doors of the ground floor.

Most of the evacuees were knowledgeable about fire safety, and the wardens were quite well-trained with the evacuation schemes. From the returned questionnaires, nearly 99% of occupants reported their age to be between 20 and 60 years. The majority of the occupants involved were male ($\approx$ 70%) and 6% of occupants indicating disabilities that could impede their evacuation.

The evacuees responded in several ways upon hearing the fire alarm and these caused different delay periods. Responses included "got dressed" (32%), "followed instructions on P.A." (12%), "went to the meeting point" (12%), "secured files/information" (11%), "continued working" (10%), "returned to office" (9%), "gathered valuables" (7%), and "others" (7%). Nevertheless, the delay time taken for each action is not clearly specified in the referenced report. Thus, some sensitivity analyses were performed using different types of pre-movement time distribution that gave delay times similar to the real incident.

6.3 Evacuation Procedure/Timeline

In case of an emergency in the Jean Talon Building a procedure manual is generally available to all staff and fire wardens. The evacuation procedure incorporates a fire alarm system that is followed by a voice communication scheme. In this evacuation drill, the able-bodied occupants were gathered at the nearest exits after hearing the alarm and then evacuated when they received the instructions from the voice communicator; whereas, the disabled occupants were told to gather at stairwell D and wait for further instructions. Evacuees were told to stay away from the building by at least 100 m when outside, and that they could only return to the building when authorized by fire officials. The approximate time frame of the evacuation drill is illustrated below with the associated incident records.

Time Frame		Incidents
Real Time	**Elapsed Time**	
1:45:53	0 s	The alarm was activated. All occupants were instructed to gather at the nearest exits.
1:47:50	117 s	Lighting conditions in each stairwell on the floors studied were altered to emergency lighting, except stairwell B.
1:50:54	301 s	All occupants started to evacuate from their floors.
1:52:07	374 s	Disabled occupants and floor emergency officers were instructed to gather in stairwell D ready to evacuate.
1:53:05	432 s	The remaining occupants started to evacuate from the building.
1:58:07	734 s	The last occupant entered the stairwell.
2:00:16	863 s	Occupants in Floors 9, 10 & 11 were all cleared.

Table 6.1: The Incident Time Frame of the Evacuation Drill in Jean Talon Building.

6.4 Modeling Scenarios

EvacuatioNZ has its limitation in modeling the occupants to wait at instructed locations for a certain period of time, even though some occupants may have their delay periods longer than the specified time. In order to match the model as closely as possible to the real incident, two scenarios were performed in accordance with the time frame described in Table 6.1. The model inputs for these two scenarios are briefly described as follows:

Scenario 1: (EvaucatioNZ & GridFlow)

Disregarding the fact that the occupants were gathered first at the nearest exits waiting for instructions, three types of pre-movement time distribution were tested with the mean results that had their maximum pre-movement time approximated to the time when the last occupant entered the stairwell. The input parameters for these three distributions are characterized below with the standard deviations X and Y as variables for sensitivity analysis. The average delay time of 180 s is extracted from Proulx (2002), whereas the maximum delay time of 662 s (734 s - 72 s) is assumed to be the time when the last occupant started to move towards the stairwell based on the real event (i.e. the average time for the occupants to travel from their original position to the nearest exit was 72 s). In this study, only the normal pre-movement time distribution was carried out using GridFlow to have a fundamental review of the total evacuation time difference compared to EvacuatioNZ.

- Delay time:
    1. Mean = 180 s, SD = X s (Normal Distribution)
    2. Mean = 180 s, SD = Y s (Lognormal Distribution)
    3. Max = 662 s, Min = 0 s (Uniform Distribution)

- **Scenario 2: (EvaucatioNZ only)**

In this scenario, the movements for both able-bodied and disabled occupants were modeled correspondingly to the real incident. For able-bodied occupants, since they left their floor at t ≈ 301 s and the average time taken for them to reach the exits from their original position was approximately 72 s, it was assumed that the able-bodied occupants had a uniform pre-movement time distribution that covers the 72 s up until the able-bodied occupants had left the floor at t = 301 s (i.e. 229 s ~ 301 s). On the other hand, the disabled occupants were instructed to gather at the stairwell entries at t = 374 s and start to evacuate through stairwell D at t = 432 s. With the intention of modeling these disabled occupants to evacuate through the instructed route, the preferred route function was utilized using EvacuatioNZ. Since the last disabled occupant entered the stairwell at t = 734 s and the average travel time was approximately 72 s, a uniform distribution of pre-movement time for disables is set to have its minimum and maximum as 374 s and 662 s. A graphical representation of the two scenarios to the real incident is illustrated below for clearer understanding of the assumed situations.

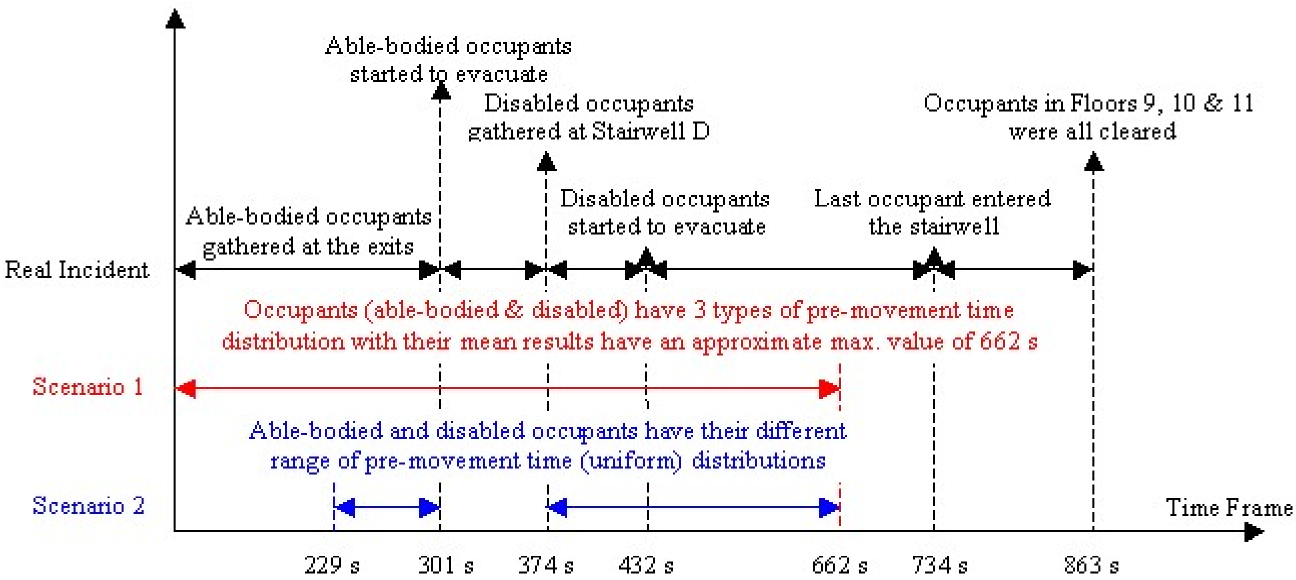


Figure 6.2: The Graphical Representation of the Two Scenarios.

6.5 Model Set-ups/Assumptions

6.5.1 EvacuatioNZ

EvacuatioNZ has several input variables within the 6 input files that allow, as close as possible, the user to model a real incident. Due to limited available information some data inputs cannot be verified in this report; however, many of the variables can be assumed according to the studies done by other researchers or from the default values within EvacuatioNZ. The model inputs and the assumptions using EvacuatioNZ are briefly summarized in the table below.

Input Type	**User Choices/Input**		
Building configuration (shown in next page)	Node and arc positions	Area of each node (usable space)	Distance from node to node (arc)
Evacuation route	All occupants choose the nearest exits		
Travel distance to stairwells	Average = 25 m		
Behaviour – queuing correlation [a]	Mixed (Nelson & MacLennan)		
Behaviour – location	Occupants are randomly distributed on each floor		
Behaviour – speed [b]	Average emergency horizontal unimpeded speed = 1.35 m/s for able-bodied; = 1.0 m/s for disabled		
Behaviour – body size [c]	MND = 2.5 ppl/m^2, LOD = 1.5 ppl/m^2		
Occupants with disabilities	6%		

Table 6.2: Inputs for the Jean Talon Building Evacuation Scheme using EvacuatioNZ.

Notes:

(a) A mixed queuing correlation is suggested from Teo (2001) that gives the most logical and realistic results.

(b) The average walking speeds on horizontal walkways for able-bodied and disabled occupants are extracted from Fahy et al. (2001) when density is not a factor.

(c) The combination of the MND and LOD suggested here is from the findings in the previous chapter when there are only small amounts of disabled occupants involved.

- Refer to Appendix C for the detailed codes of the 6 input files using EvacuatioNZ.

Geometry Set-up (EvacuatioNZ)

As presented in the previous chapter, EvacuatioNZ has the advantage of using simple node configuration for complex floor layouts that give comparable results with detailed geometry set-ups. Therefore, each floor and the stairways connecting each two floors are both assumed as single nodes for this 13-storey office building. A total of 47 nodes are required to model this evacuation scheme.

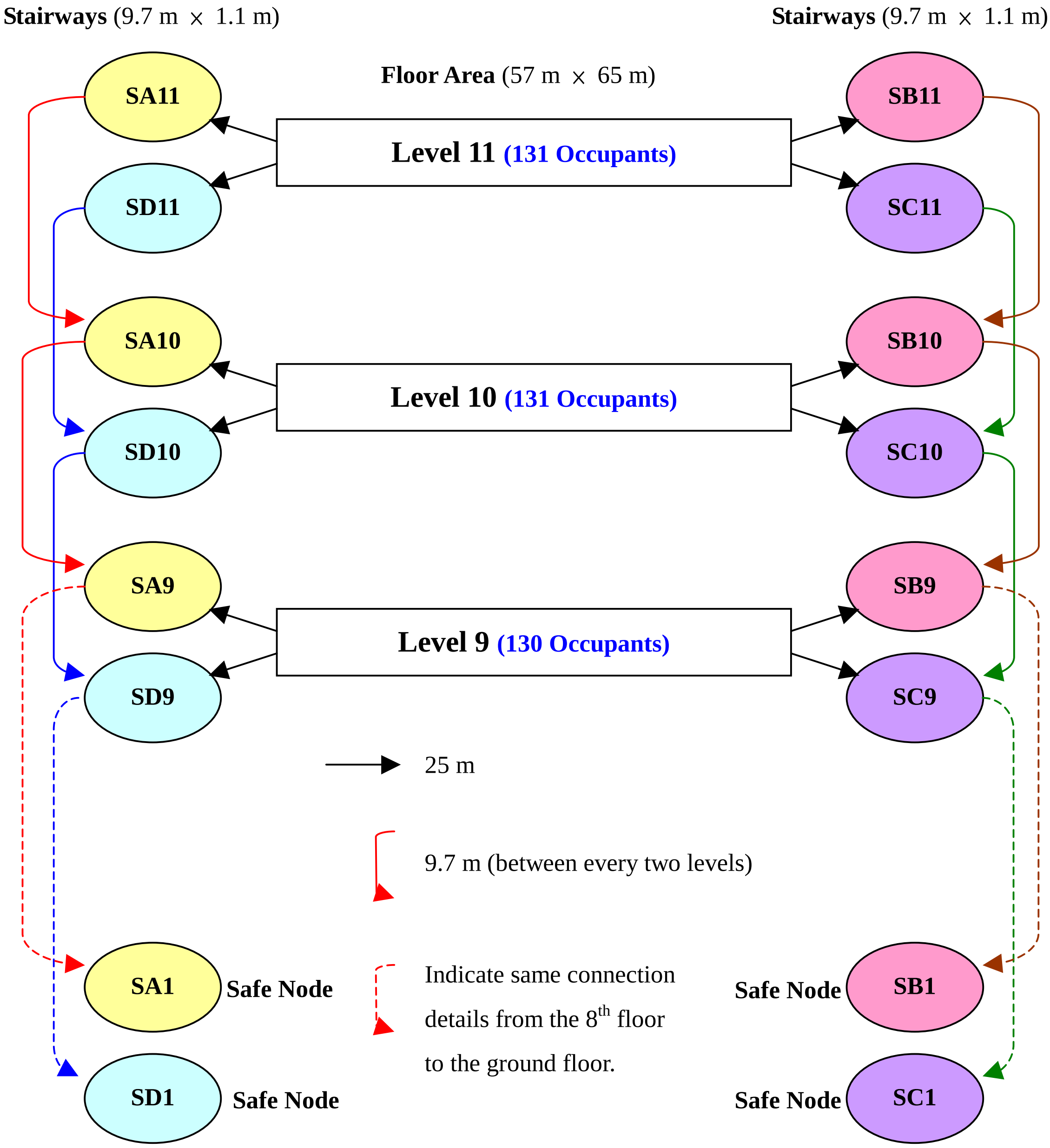


Figure 6.3: The Geometry Set-up using EvacuatioNZ.

6.5.2 GridFlow

GridFlow is able to represent each individual's movement as well as interactions between occupants and obstructions during the course of an evacuation system. The behavioural inputs of the model are considered simple and transparent and can be extracted from the empirical data or specified by users. When model occupants move horizontally and on stairs, the program incorporates similar speed/density correlations as does EvacuatioNZ, and therefore, is able to present comparable results for this evacuation scheme (i.e. equations in Nelson et al, 2002).

For this 21-storey office building, the floor layout was manually drawn using the tools in the "Block" function rather than extracted from CAD drawings. The stairwells were also created manually with the connections to the three floors, and lead downwards to the final exits (detailed geometry set-ups are shown on the next page).

Due to the fact that there were no fire products presented during the trial evacuation, the input of the FED susceptibility that relates to the conditional behaviour was ignored. The overall inputs were similar to the EvacuatioNZ model while normal pre-movement time distribution was used.

Input Type	User Choices/Input
Building configuration	Manually drawn using "Block" function
Evacuation route	All occupants choose the nearest exits
Behaviour – location	Occupants are randomly distributed on each floor
Behaviour – speed	Average emergency horizontal unimpeded speed = 1.35 m/s for able-bodied; = 1.0 m/s for disabled
Behaviour – conditional	No FED susceptibility/Smoke blockage
Delay time	Normal distribution
Occupants with disabilities	6%

Table 6.3: Inputs for the Jean Talon Building Evacuation Scheme using GridFlow.

Geometry Set-ups (GridFlow)

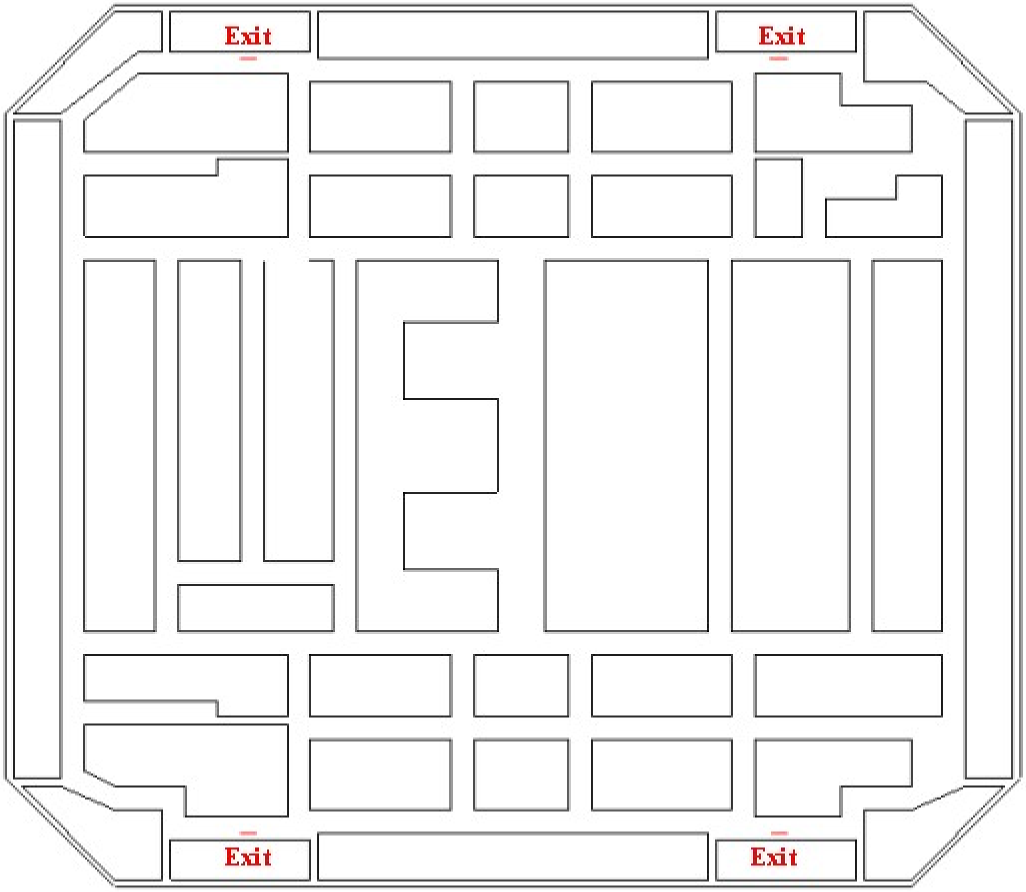


Figure 6.4: The Floor Plan of the Jean Talon Building using GridFlow.

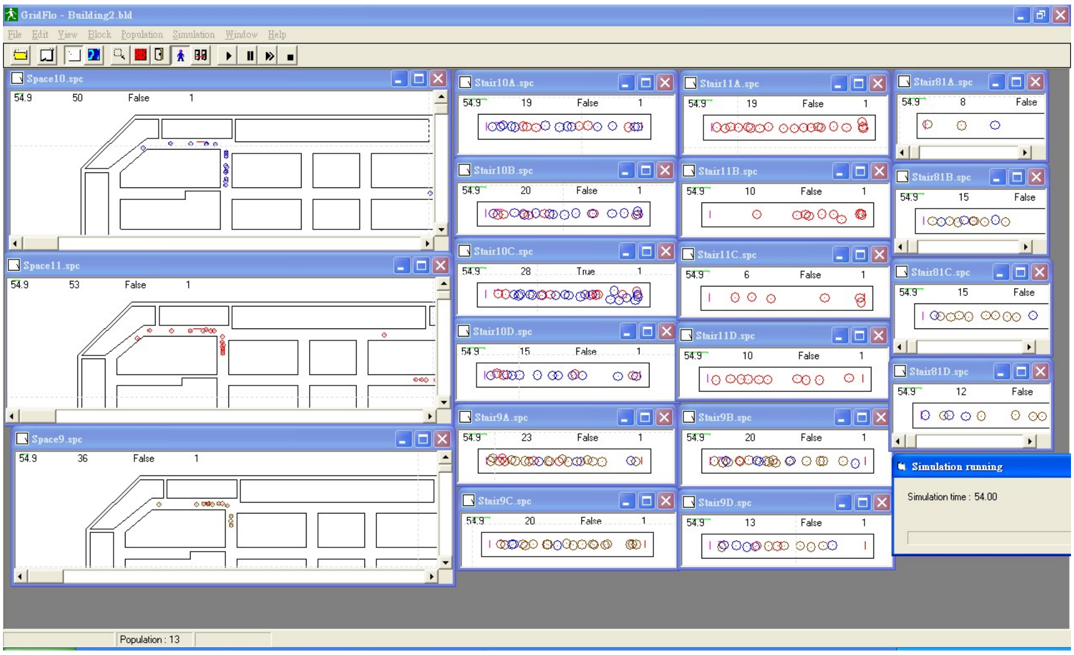


Figure 6.5: The Linkage of the Stairways using GridFlow.

6.6 Sensitivity Analysis/Results

6.6.1 Scenario 1 & 2

Scenario 1

Practically, the actual delay period for each occupant can hardly be determined in an evacuation scheme. Modelers can only use approximations based on the experiments done by previous researchers in different types of situations, or use estimates that incorporate the real time frame. In this scenario, to disregard the fact that the occupants were gathered at the exit doors waiting for instructions after hearing the alarm, three types of pre-movement time distributions were tested using EvacuatioNZ. These included normal, lognormal and uniform distributions.

In order to find the best match with the real total evacuation time, some sensitivity analyses were carried out using these arbitrarily standard deviations (SD) for both the normal and lognormal pre-movement time distributions. Once the appropriate SDs were found, further investigations were then performed on the simulated or distributed range of the occupants' pre-movement times to see whether they match well with the time when the last occupant started to move towards the stairwell (i.e. have a approximate maximum of 662 s). The functional inputs for the three distributions using EvacuatioNZ are shown in the table below.

Distribution Type	Input Variations
Lognormal (3 tests)	Mean = 180 s SD = 60 s, 90 s, 120 s
Normal (3 tests)	Mean = 180 s SD = 150 s, 180 s, 210 s
Uniform	Max. = 662 s, Min. = 0 s

Table 6.4: The Inputs for the Lognormal, Normal, and Uniform Pre-movement Time Distributions.

Proulx et al (1999) recorded a total time of 863 seconds for all 392 occupants to safely evacuate from the office building. In this scenario, the assumed conditions of the pre-movement time seem to give comparable results using EvacuatioNZ, for which the average total evacuation times (out of 100 batch runs) in each test are summarized in Figure 6.6. The figure also indicates that the use of uniform distribution is good enough to give sensible approximations, whereas the normal and lognormal distributions vary their results with the defined standard deviations.

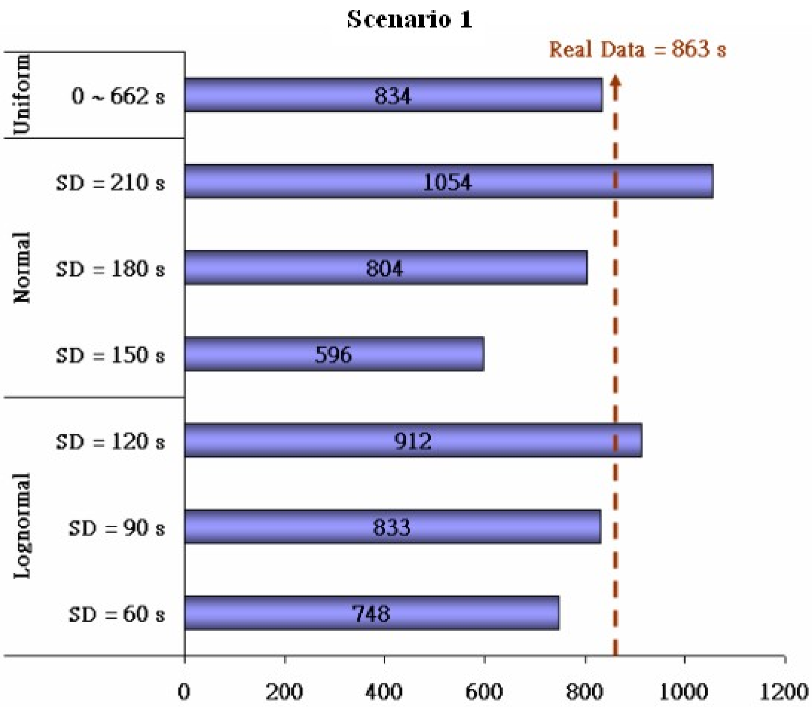


Figure 6.6: The Comparison of the Simulation Results using the Three Distributions.

Realistically, the larger the standard deviation of the pre-movement time distribution the more likely the occupants have longer delays resulting in higher total evacuation times. This phenomenon can be clearly seen in Figure 6.7 and Figure 6.8, which show the distribution of the simulation results for both normal and lognormal delays with different standard deviations. Graphically, the optimal standard deviation for the normal and lognormal delays appears to be 180 s and 90 s, respectively.

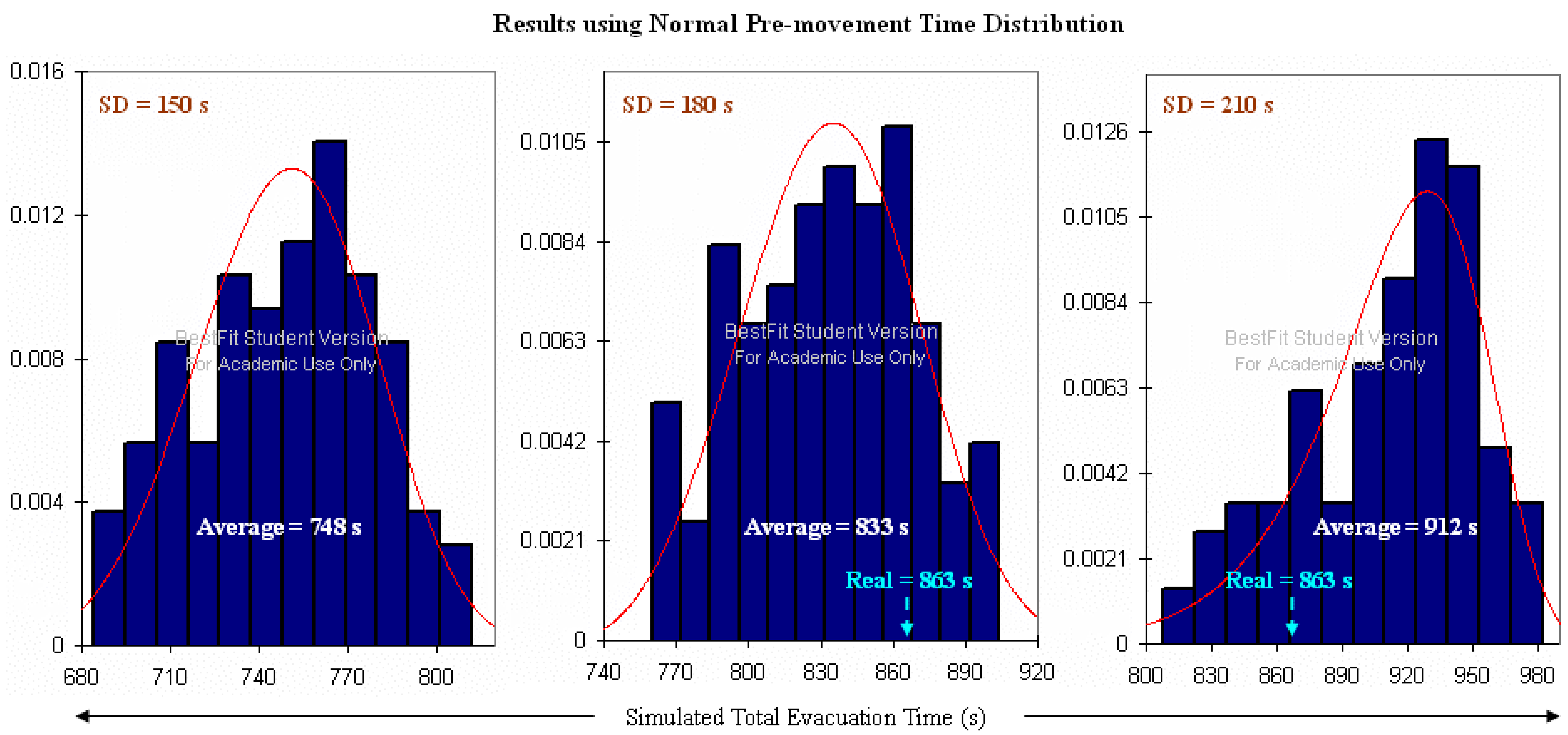


Figure 6.7: The Comparison of the Simulated Total Evacuation Times using Normal Pre-Movement Time Distribution with Different Standard Deviations.

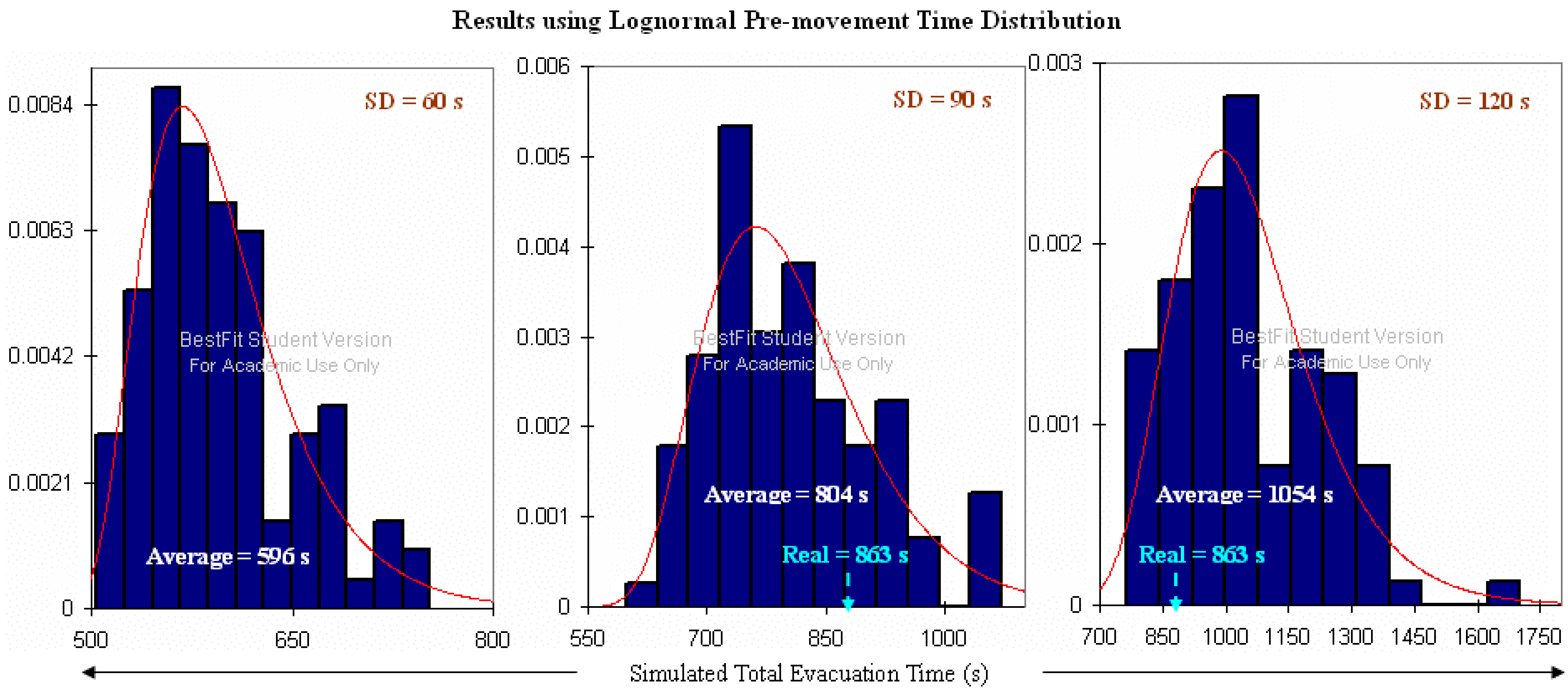


Figure 6.8: The Comparison of the Simulated Total Evacuation Times using Lognormal Pre-Movement Time Distribution with Different Standard Deviations.

Nevertheless, the range of the delay periods simulated by these optimal standard deviations still needs to be verified in accordance of the assumed situation (i.e. approximated maximum of 662 s). Therefore, the simulated delay periods for the 392 evacuees were extracted from one of the batch runs that had its total evacuation time similar to the mean of the simulated results (out of 100 simulations). These are shown in Figure 6.9 and Figure 6.10 for the three distributions. These figures indicate that those optimal SDs found for the normal and lognormal distributions and the defined range of the uniform distribution not only could give sensible estimations on the total evacuation time, but also their approximations on the occupants' delays were comparable to the assumed situation. Consequently, this verifies that by knowing the desired input parameters of the pre-movement time function, EvacuatioNZ is able to generate sensible approximations on the total evacuation time on high-rise building analysis.

Furthermore, from the shape of these generated delays they also verify the functional integrity of the three type pre-movement time distributions within EvacuatioNZ. Nevertheless, it should be noted that the delay times simulated using the normal distribution seems to only have half side of its defined shape. This occurrence is because the occupants' delay only had a small mean (180 s) but a large SD (180 s) that generated high total evacuation times to reach the desired range. Practically, the negative delays are not generated within the program since they do not reflect real situations.

So far, by looking at the results simulated in this scenario, the use of simple node configuration and the optimal combination of MND and LOD (small% disables) seem to generate satisfactory results compared to the real data.

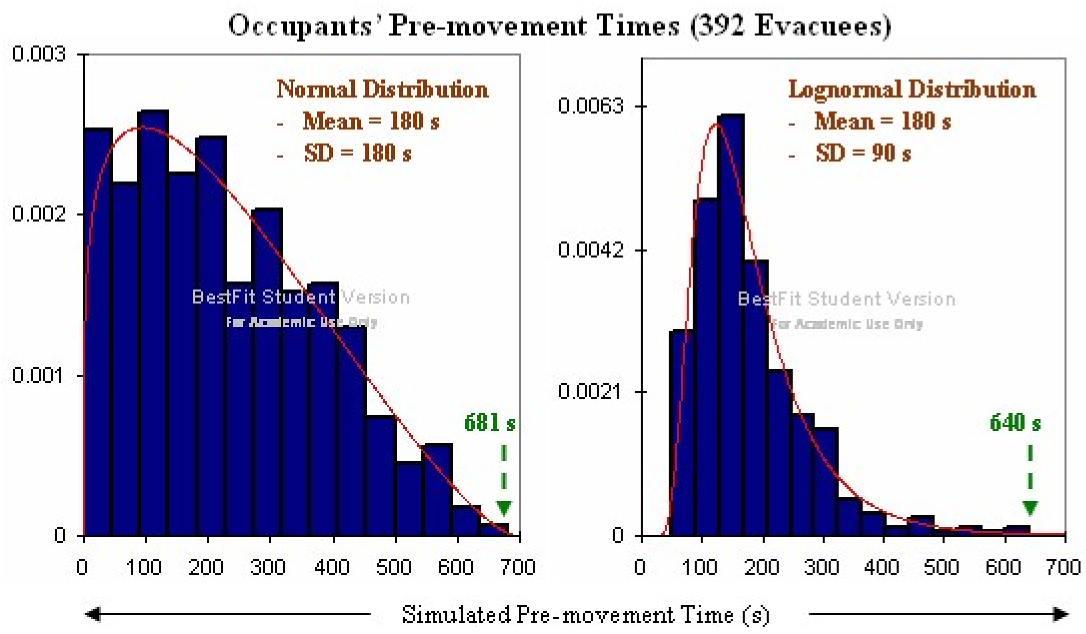


Figure 6.9: The Spread of the Pre-movement Times for the 392 Evacuees using Normal and Lognormal Pre-movement Time Distributions.

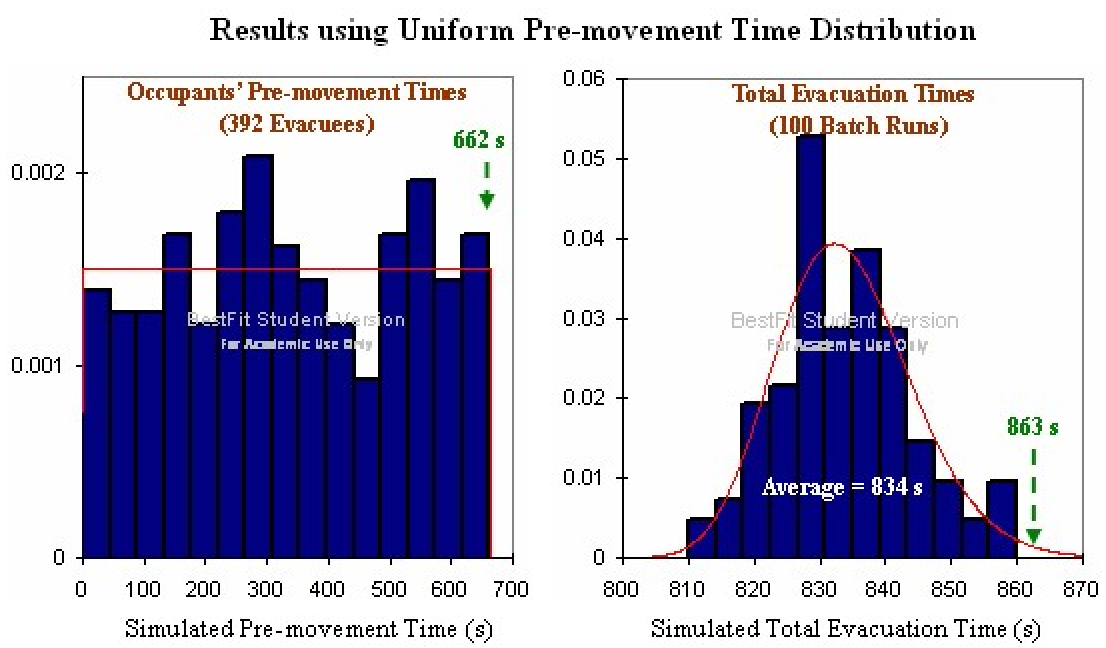


Figure 6.10: The Pre-movement Times of the 392 Evacuees and the Distribution of Total Evacuation Times using Uniform Pre-movement Time Distribution.

Figure 6.11 is a graphical representation of the simulation results from 100 batch runs using normal pre-movement time distributions both in EvacuatioNZ and in GridFlow. The mean and SD used in both models are from the sensitivity analyses done in the previous part of this scenario (i.e. mean =180 s, SD = 180 s).

By comparing both the average total evacuation times, which were simulated by EvacuatioNZ and GridFlow, there was about 13% difference. With other similar inputs, GridFlow seems to generate longer total evacuation times than EvacuatioNZ. This may be due to the fact that unlike GridFlow, EvacuatioNZ does not take account of body interference as well as impediments due to obstacles. Thus, occupants in each node travel directly to the exits without experiencing any body effects, but are influenced by the density of the existing population. Overall, the total evacuation times that were simulated using the conditions assumed in this scenario are generally reasonable when compared to the real data and GridFlow simulations. Therefore, they provide some degree of confidence in the use of the EvacuatioNZ model on high-rise building analysis.

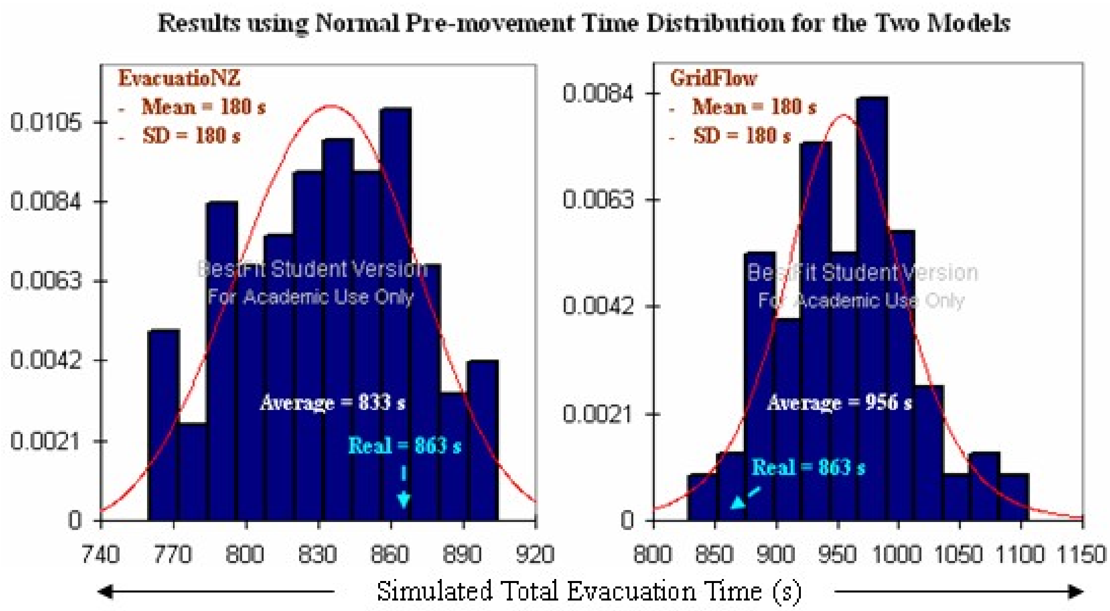


Figure 6.11: The Comparison of the Simulation Results generated by the Two Models.

Scenario 2

The delay periods for both able-bodied and disabled occupants were simulated using uniform distribution, which was previously found to be an appropriate assumption in this evacuation scheme. The spread of the pre-movement time is similar to that in Scenario 1, except in this case the occupants had a narrower range of delay periods, particularly for the able-bodied occupants. Practically, the able-bodied occupants were instructed to gather at the exit doors after hearing the alarm, which consequently created a large queuing effect. The use of a narrow distribution range in occupants' delay periods could produce a similar effect since the occupants moved towards the exits at nearly the same time.

The mean and distribution that were generated from the simulation of 100 batch runs are shown in Figure 6.12. The results closely followed a normal distribution with a mean of 827 s, which compared to the real time that all occupants evacuated from the building has only a 4.2% difference. Further, the mean simulated here is quite close to the mean (= 833 s) simulated using the uniform distribution in Scenario 1, but does have a better coverage that also includes the real time data (as shown in Figure 6.12). Realistically, the simulated results might not be a perfect match with the real data due to the fact that many of the model inputs were hypothesized. However, the results shown in this scenario appear satisfactory, and subsequently provide some level of confidence when EvacuatioNZ is used for high-rise building analysis.

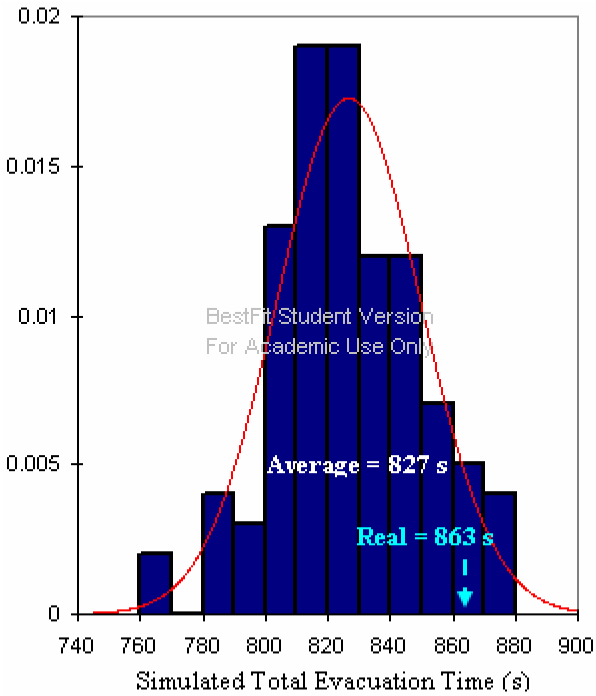


Figure 6.12: The Simulation Results for Scenario 2.

6.6.2 Occupants Movement under Different Lighting Conditions

During this evacuation drill, four different lighting conditions were tested to examine their effects on occupant travel speed while descending to the ground floor. The actual lighting condition in each stairwell is illustrated in Figure 6.13, where the PLM is referring to the photoluminescent material. Basically, the actual lighting condition in each stairwell was not considered as an influential input for the simulations done in both Scenario 1 and 2. It is uncommon for the current available evacuation models to have such a function that incorporates stairwell lighting system with occupant travel speed. Nonetheless, this feature has been created within EvacuatioNZ to determine its effect on the estimation of total evacuation time while a large number of occupants are involved in an evacuation scheme.

Figure 6.13: Lighting Conditions in the Four Stairwells. (Proulx et al, 1999)

Besides, the pre-movement times for the evacuees were based on the assumed conditions in Scenario 2, which was found to be an appropriate assumption for this particular drill (as discussed previously). The analyses in this section not only focused on the influence of lighting condition on the total evacuation time, but also on the flow of the occupants exiting through the stairwells. The analytical results are briefly discussed as follows:

Total Evacuation Time

Figure 6.14 shows the distribution of the simulated total evacuation times of 100 batch runs with or without lighting effects in the stairwells. The results indicate that even though occupants may travel slower or faster in different lighting conditions, it only has minor impacts on the total evacuation time. This is due to the fact that when a large population is involved, the queuing effect or the occupant density becomes the major control of estimating total evacuation time. Here, not only does the average result between these two conditions have only a 1.5% deviation, but also they produce a similar range of distributed results.

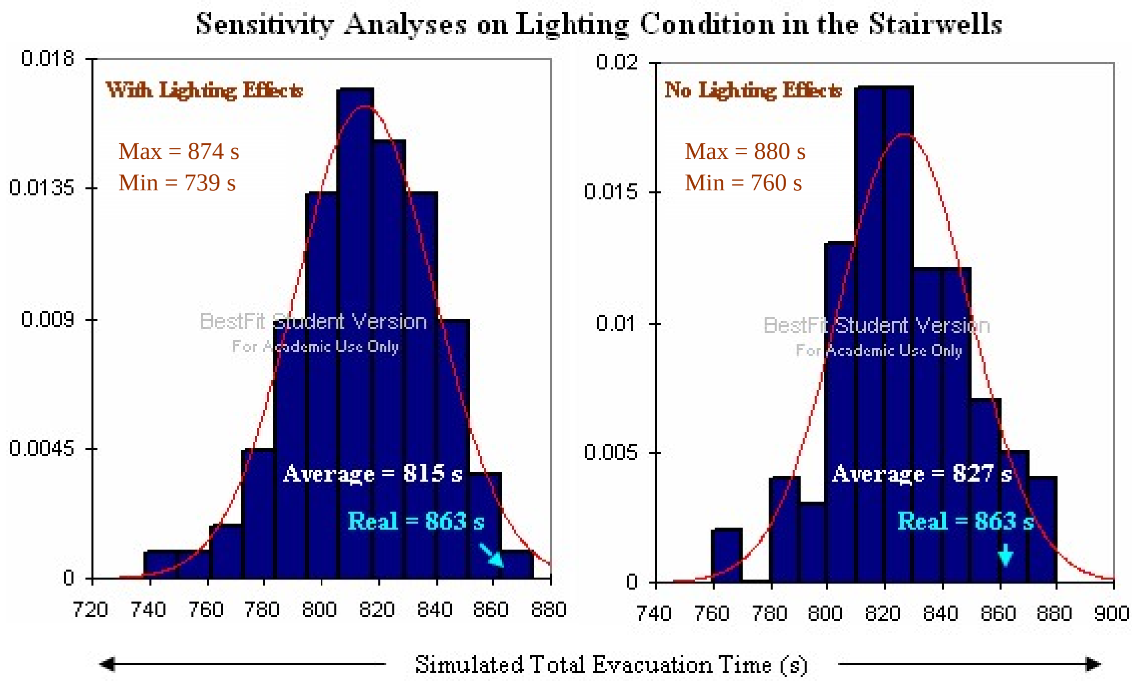


Figure 6.14: The Comparison of the Simulated Total Evacuation Times with and without Lighting Effects in the Four Stairwells.

As mentioned in Chapter 4, EvacuatioNZ incorporates the Monte Carlo approach which is capable of generating a probability distribution that covers a range of uncertainties. Hence, even though the lighting condition in the stairwells may have some effects on the occupants' travel, these effects can be resolved by generating sufficient batch runs to create a confidence range of total evacuation times.

Occupants Flow in the Stairwells

Further investigations were carried out to look at how each lighting condition affected the flow of the occupants exiting through the stairwells based on a single batch run having the same endpoint (total evacuation time). Figure 6.15 shows an overview of how lighting systems can affect the flow of exiting occupants. These simulations had their total evacuation time as 863 s with and without lighting effects. The occupants flow without the effects of lighting seems to be quite consistent in the four stairwells, but when the effects of lightings were involved, the results indicate some minor deviations on the occupants' flow in the four stairwells.

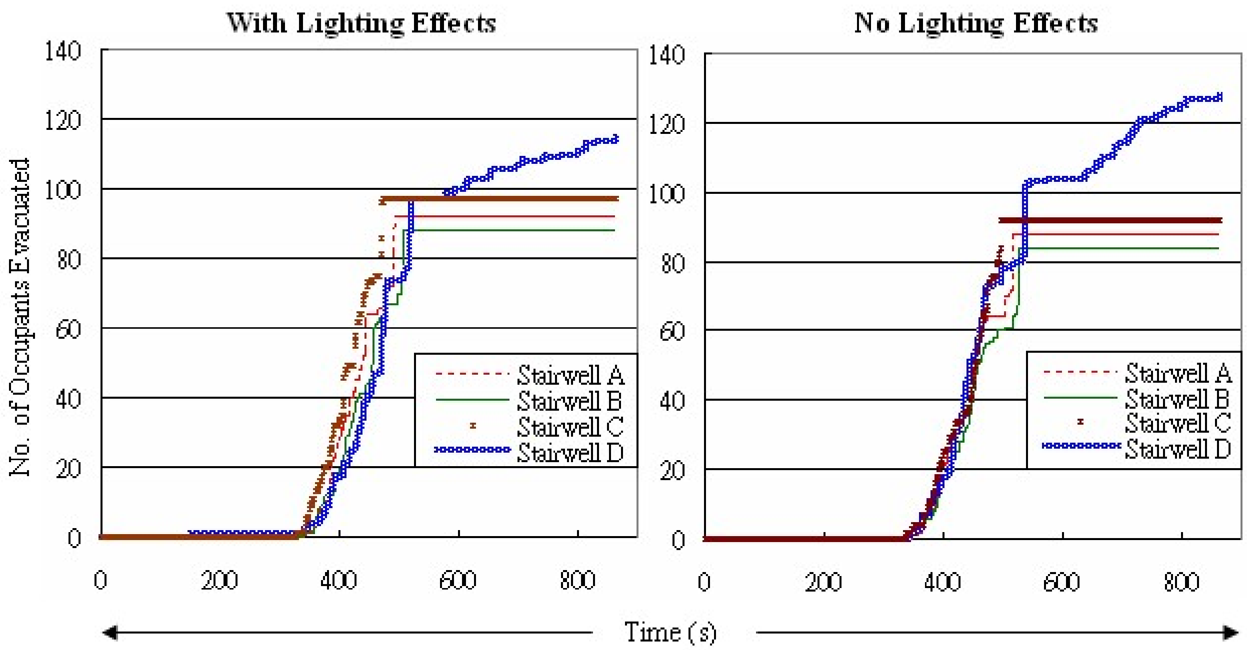


Figure 6.15: Comparison of the Occupants' Flow with and without Lighting Effects in the Stairwells.

Further in the same batch runs, when looking at the comparisons of the occupants' flow in each stairwell with and without lighting effects (as shown in the figures below) they appear to only have slight variations on the occupants' flow. Other factors that might cause these variations were the number of occupants exiting through each stairwell and their traveling speeds in different simulation runs. However, these influences seem to have no considerable impact on the estimation of total evacuation times, which further demonstrates that even though occupants' travel may be slightly affected by the existing lighting, the density of the exiting occupants should be the major control on the estimation of the total evacuation time.

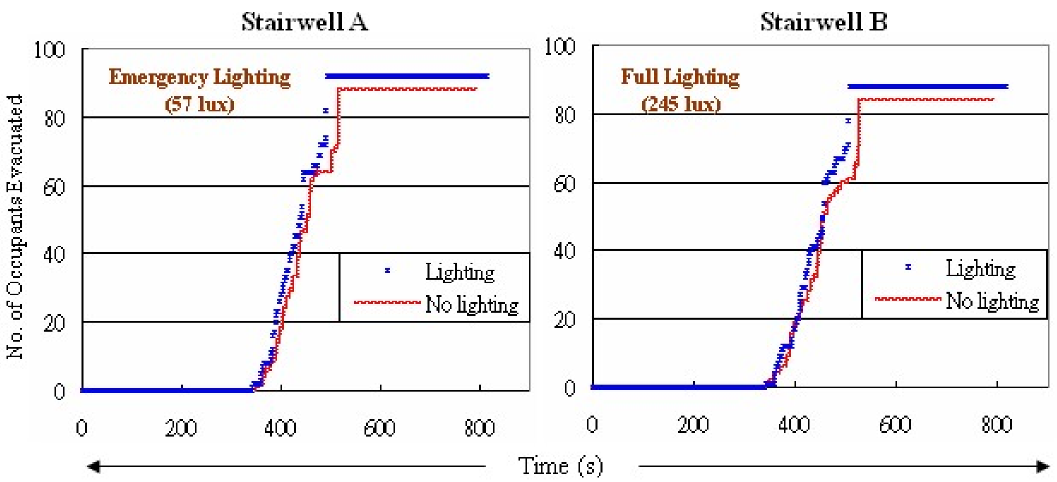


Figure 6.16: Comparisons of Occupants' Flow in Stairwell A and B with and without Lighting Effects.

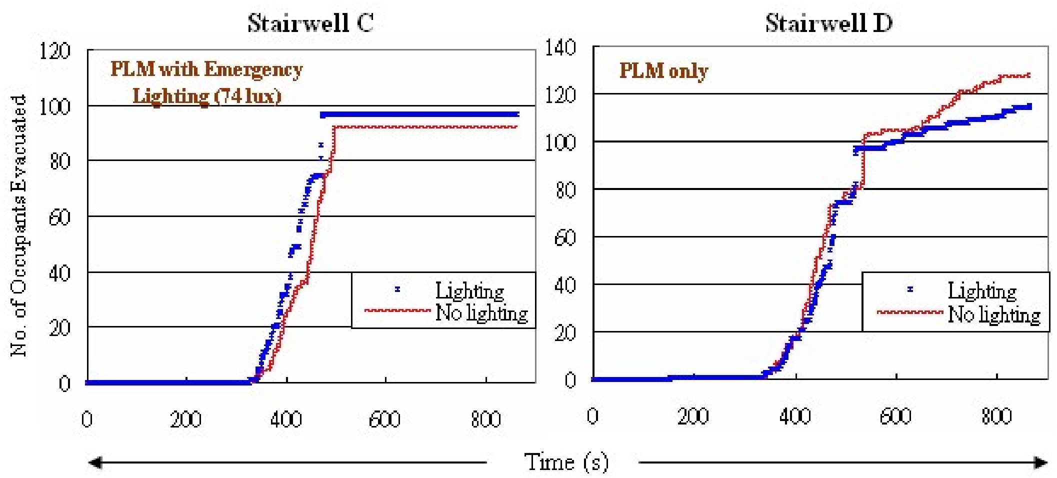


Figure 6.17: Comparisons of Occupants' Flow in Stairwell C and D with and without Lighting Effects.

6.7 Conclusions

The analyses done using Scenarios 1 and 2 have verified the functional integrity of the pre-movement time distributions within EvacuatioNZ. Model users should be confident to input the likely parameters of the distribution function and get reasonable predictions on the time for occupants to travel from one place to another.

Besides, EvacuatioNZ seems to generate quicker total evacuation times than GridFlow. This is due to the fact that the two models have their differences in simulating occupants' movement towards body interactions and obstacles even though they utilize the same predictions on the occupant travel speed horizontally and on stairs.

The validation exercise regarding lighting conditions in the stairwell seems to agree with the findings in Proulx's study. Even though the occupants' flow may be slightly affected by the existing lighting condition, the total evacuation time can hardly be influenced.

Even though the overall results represent good approximations on the total evacuation time that validate the findings in the previous chapter (such as the simple node configuration and optimal MND and LOD combination), EvacuatioNZ still needs to be further developed to efficiently model controlled evacuation schemes. Some limitations were also found during the modeling process using EvacuatioNZ, which are discussed in Section 8.1. Nonetheless, further validations were carried out to look at how the EvacuatioNZ model could perform when the occupants in all levels are evacuated. These details are briefly discussed in the next chapter.

7.0 Trial Evacuation on a 21-Storey Office Building

A trial evacuation was performed on a 21-storey office building located in Brisbane (Australia); however, the collected evacuation data has not yet been published for general applications. Even so, the fire drill was conducted in a rational manner with all the occupants in the 21 floors evacuated in an uncontrolled evacuation sequence (i.e. the entire building evacuated at the same time). Therefore, it is worthwhile to use it as another implementation on validating the functional integrity of the EvacuatioNZ model.

Also, the estimated delays for the occupants involved in this fire drill were based on Weibull distribution, which is generally considered as a useful tool that provides accurate measures of pre-movement times even with small data samples (MacLennan et al, 1999). The utilization of this type of pre-movement time within EvacuatioNZ needed to be verified, particularly on the alternation of the real delay times to the two parameters (shape factor and scale factor) associated with Weibull distribution.

Sensitivity analyses were carried out based on the input function of maximum travel speed. The previous analyses done on the 21-storey hotel building and the 13-storey office building had assumed constant travel speed. However, during this phase the EvacuatioNZ model was then further developed to allow the user to functionally input the speed using distributions. Realistically, occupants travel differently due to their dissimilar characteristics, such as age, gender, mental reactions, and several other factors. The use of speed distribution can generalize these uncertainties and produce more realistic results.

7.1 Building Descriptions

The exercise was carried out in the AXA Building in Brisbane, Australia. The building was composed of 20 office floors with retail shops in the ground floor, and two levels of basement car parks. Geometrically, it has a rectangular appearance that is uniform throughout the building with an approximate area of 769 m^2 in each level. The building was fully protected with sprinklers and fire warning systems.

Each office floor is basically divided into two sections that connect to a common lobby as shown in Figure 6.1. Generally, occupants access each level by either the stairwells or the lifts. In this evacuation scheme, occupants were instructed to only use the two stairwells, which are indicated in the figure below. Each stairwell has a clear width of 1.06 m between the handrail and the wall, and 7.3 m in length between every two levels.

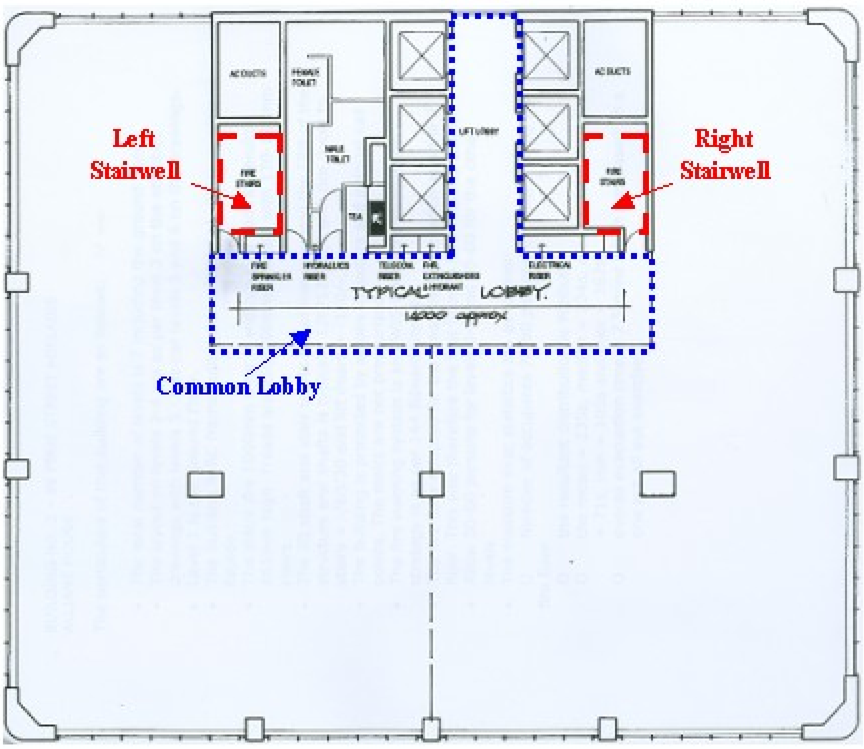


Figure 7.1: The Typical Floor Plan of the AXA Building.

7.2 Evacuees

The exercise was carried out during office hours when each floor was estimated to contain 40 to 75 office workers in the AXA building. The exact number of occupants in each level was not recorded except on the 18^{th} level, where the pre-movement times for the 70 evacuees were observed. Thus, an average number of 58 occupants were assumed for the rest of the floors in this evacuation scheme. A total of 1172 occupants were estimated to have participated in this evacuation scheme. Principally, these occupants were said to be "safe" once they reached the stair door of the ground floor.

Based on the observations, the measured delay periods in the 18^{th} level could suitably be represented using Weibull distribution (evacuation statistics are summarized in Table7.1). The occupants in other levels were assumed to follow similar evacuation pattern as in the 18^{th} level since they have comparable building geometries and occupancy type.

Delay Periods	Mean	Median	Mode	Std Dev	Min.	Max.
	208.5 s	204 s	167 s	136.9 s	72 s	932 s

Table 7.1: The Measured Evacuation Statistics of the 70 Occupants in the 18^{th} Level.

Furthermore, the author who conducted this evacuation indicates an approximated quantity of 8% disabled occupants among the evacuees. There is no clear specification on the limitations of these 8% disabled people. However, when there are only a small proportion of disabled people involved, it is worthwhile to use this group to further verify the optimal combination of MND and LOD functions within EvacuatioNZ (as was the conclusion in Chapter 5).

7.3 Model Set-ups/Assumptions

Basically the AXA building was modeled using a simple form of node arrangements. From the analyses done in Chapter 5 this arrangement was verified as being capable of providing satisfactory results. The modeling techniques in the MAP file are very similar to the 21-storey hotel building hypothesized in Chapter 5 as they have an identical number of floors and stairwells. Nevertheless, there were still a few parameters within the MAP file that needed to be altered. These regarded dimensions of geometry layout and distances in each connection

Practically, the pre-movement times were observed and measured at the two exits of the 18th floor. This meant that the recorded pre-movement times also included the time that occupants travel from their original position to the stairwells. Even so, in order to account for this situation, EvacuatioNZ has the advantage of entering the connection distance between the floor and the stairwell to be minimal (assumed as 1 m in this case).

As previously mentioned, the occupants' travel speeds, both on a walkway and on a stairway, can be adequately presented by a normal distribution. Therefore, in order to test the recent development of this speed distribution function, some sensitivity analyses were carried out with occupants' maximum speeds as constants or as normal distributions. The mean speeds for able-bodied and disabled occupants with probable standard deviations and other inputs, which were used in this evacuation scheme, are summarized in Table 7.2,

Refer to Appendix D for the detailed inputs of this evacuation scheme using EvacuatioNZ.

Input Type	**User Choices/Input**		
Building configuration	Node and arc positions	Area of each node (usable space)	Distance from node to node (arc)
Evacuation route	All occupants choose the nearest exits		
Travel distance to stairwells	Average = 1 m		
Stairways [(a)]	Riser = 0.185 m, Tread = 0.255 m		
Behaviour – queuing correlation [(b)]	Mixed (Nelson & MacLennan)		
Behaviour – response time[(c)]	Weibull distribution, α = 233, β = 3		
Behaviour – location	Occupants are randomly distributed on each floor		
Behaviour – speed [(d)]	Emergency horizontal unimpeded speed = 1.35 ($\pm$ 0.3) m/s for able-bodied; = 1.0 ($\pm$ 0.3) m/s for disabled		
Behaviour – body size [(e)]	MND = 2.5 ppl/m^2, LOD = 1.5 ppl/m^2		
Occupants with disabilities	8%		

Table 7.2: Inputs for the AXA Building Evacuation Scheme using EvacuatioNZ.

Notes:

(a) The dimensions of the riser and tread are the average values of the measurements taken from the author who conducted this evacuation scheme.

- Riser: 0.180 ~ 0.190 m Tread: 0.250 ~ 0.260 m

(b) A mixed queuing correlation is suggested from Teo (2001) that gives the most logical and realistic results.

(c) The detailed calculations for the determination of α and β are illustrated on the next page.

(d) The average walking speeds and the standard deviations on horizontal walkways for able-bodied and disabled occupants are extracted from Fahy et al. (2001) when density is not a factor. The bracketed SDs are based on normal distribution, and are used as a different case for comparisons to the constant traveling speeds.

(e) This optimal combination is based on the concluded results specified in Chapter 5 of this report when there is only a small amount of disables involved, and is used here as a further implementation on its functional reliability within EvacuatioNZ.

Pre-movement Time (Weibull distribution)

In EvacuatioNZ, the data input of the pre-movement time using Weibull distribution can not directly be entered with the real measurements, such as the mean, standard deviation, and the distribution range; but rather can be characterized using the two functions, named scale parameter (α) and shape parameter (β). MacLennan et al (1998) has clarified the method of estimating pre-movement time that is associated with these two parameters by expressing two useful equations:

$$F(x) = 1 - \exp\left[-\left(\frac{x}{\alpha}\right)^{\beta}\right] \qquad [7.1]$$

Where F(x) = the fraction of people who have finished their pre-movement time

x = time elapsed (s)

α = scale parameter

= the time at which 63.2% of people have left the system

β = shape factor

$$MTTLPS = \alpha \times \Gamma\left(1 + \frac{1}{\beta}\right) \qquad [7.2]$$

Where, $MTTLPS$ = mean time taken to leave the pre-evacuation system (s)

Γ(x) = standard gamma function

Mathematically the gamma function, Γ(x), is an intricate parameter. When its use from factorial function to complex and non-integer numbers is extended, it often requires complicated numerical calculations, as in Equation [7.2]. Even so, users may be able to simply use the GAMMAIN function in the Excel spreadsheet to work out the scale parameter (α) once the mean time and the shape parameter (β) are known.

Functionally, the shape factor (β) represents the likely form of the Weibull distribution with respect to time. From the evacuation statistics shown in Table 7.1, the pre-movement time distribution is likely to have a bell shape with a mean and a standard deviation that looks like β = 3 in the figure below. Thus, the shape factor is assumed to have the value of 3 in this evacuation scheme for the approximation of pre-movement times.

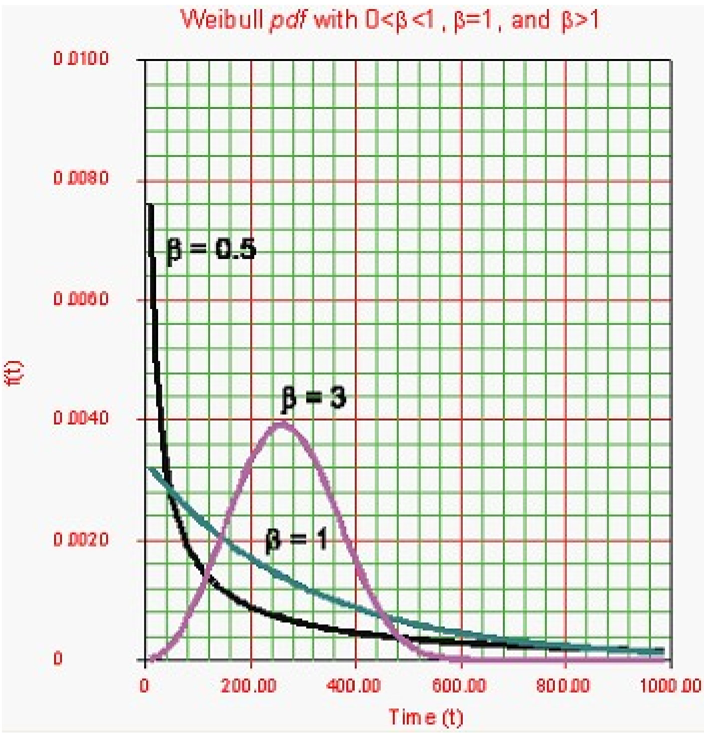


Figure 7.2: The Effect of the Shape Parameter (β) on the Weibull pdf. (ReliaSoft, 2005)

With the mean and the assumed shape factor, the scale factor was then found using Equation [7.2] using back calculation of the GAMMAIN function in the Excel spreadsheet.

- $208.5s = \alpha \times \Gamma\left(1+\frac{1}{3}\right)$ → (Using GAMMAIN in Excel to find out what value the inverse of this gamma function is.) → $IN\left(\Gamma\left(1+\frac{1}{3}\right)\right)$ → -0.1132

Find the value of the gamma function by using the Log function to neutralize the IN function.

$Log(-0.1132) = 0.893$

➢ $208.5s = \alpha \times 0.893$

➢ $\alpha = 233$

It is noted that only the mean value in Table 7.1 could be applied to find the optimal values for α and β using Equation [7.2]. Even though the simulated pre-movement times for the evacuees might not match well with the recorded data (such as the median, mode, minimum, and maximum), the simulated delays still give a similar mean that is associated with a distributed range that covers the majority of the evacuees.

Nevertheless, due to the fact that in this evacuation scheme the occupants' flow was mainly controlled by the queuing effect at the exits on each level, the total evacuation time would not be affected much with dissimilar median, mode, or even the maximum delays. This could also be explained by comparing the real total evacuation time (1800 s) to the maximum delay period (932 s) as the travel time even for a disabled occupant from the top floor to the ground floor would not take more than 900 s in this AXA building. This claim is illustrated by the following calculations:

- Estimated stairwell length from top floor to the ground floor -

  = 20 levels (connections) $\times$ 7.3 m = 146 m

- Estimated travel speed for a disabled person -

  = 1.0 m/s (average)

➢ Estimated total time required for a disabled person to travel from top floor to the ground floor -

  = 146 m $\div$ 1.0 m/s = 146 s < 900 s

Therefore, the pre-movement times for the evacuees could be sufficiently represented with a Weibull distribution that had a scale parameter of 233 and shape parameter of 3 for both able-bodied and disabled occupants.

Geometry Set-up

Using the EvacuatioNZ model, each floor and the stairways connecting each two floors are both assumed as single nodes. A total of 61 nodes are required to model this evacuation scheme. The detailed connections and the input geometries are shown in the figure below.

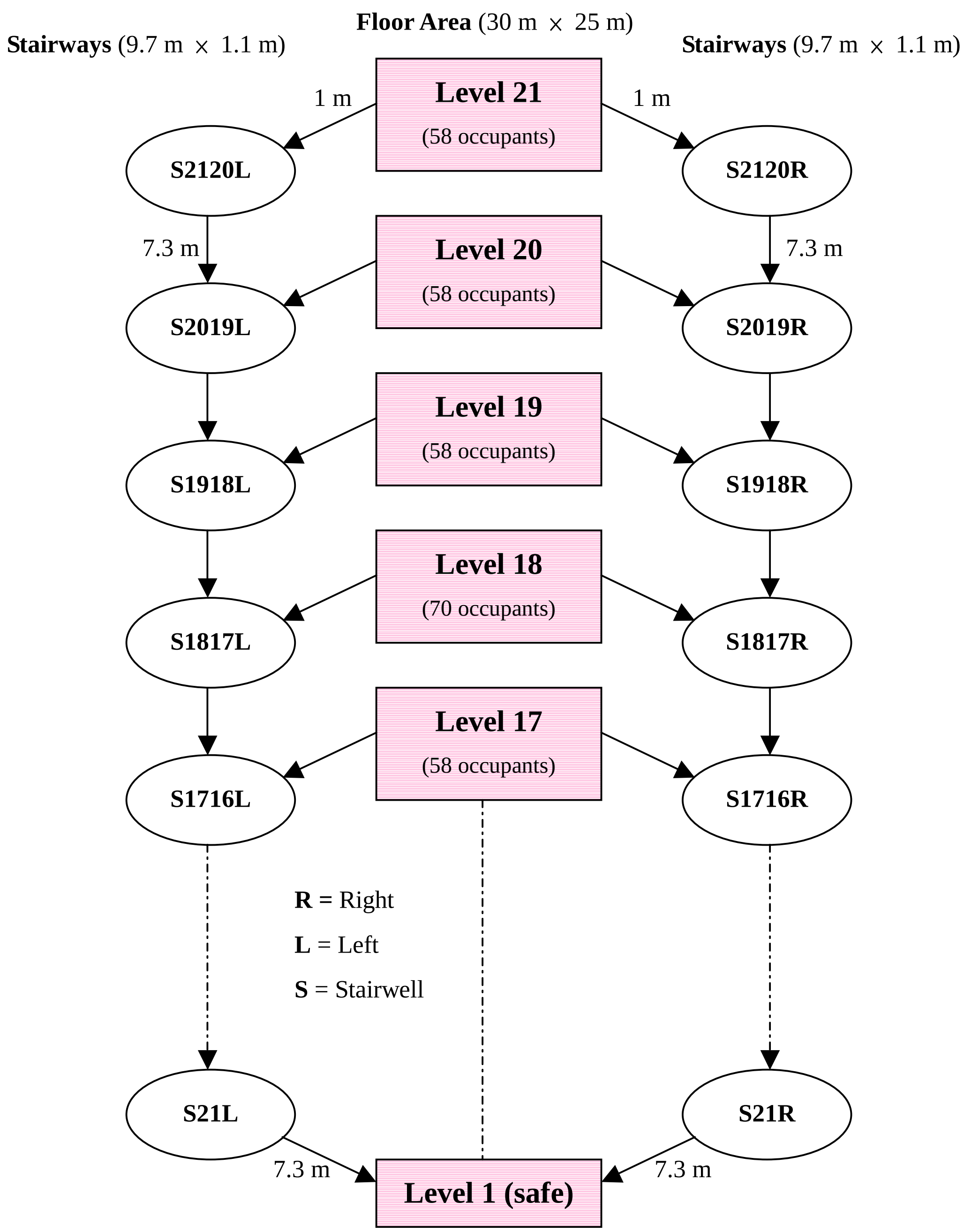


Figure 7.3: The Geometry Set-up using EvacuatioNZ.

7.4 Sensitivity Analysis/Results

Once the data inputs were created, 100 batch runs were performed with either constant traveling speed or normal speed distributions for both able-bodied and disabled occupants. Practically, there should not be much variation on the estimation of total evacuation time between these two cases as the occupants' flow was essentially controlled by the density of the large population. Even so, it is still worthwhile to have a fundamental review on the functional efficiency of the maximum speed distributions within the EvacuatioNZ model.

Because only limited information is supplied by the author due to confidential grounds, the simulated results could only be compared to a single recorded value (1800 s). However, the comparisons are still meaningful in that they provide a general overview on the effectiveness of the EvacuatioNZ model on high-rise building analysis. The overall results are illustrated in the figure below.

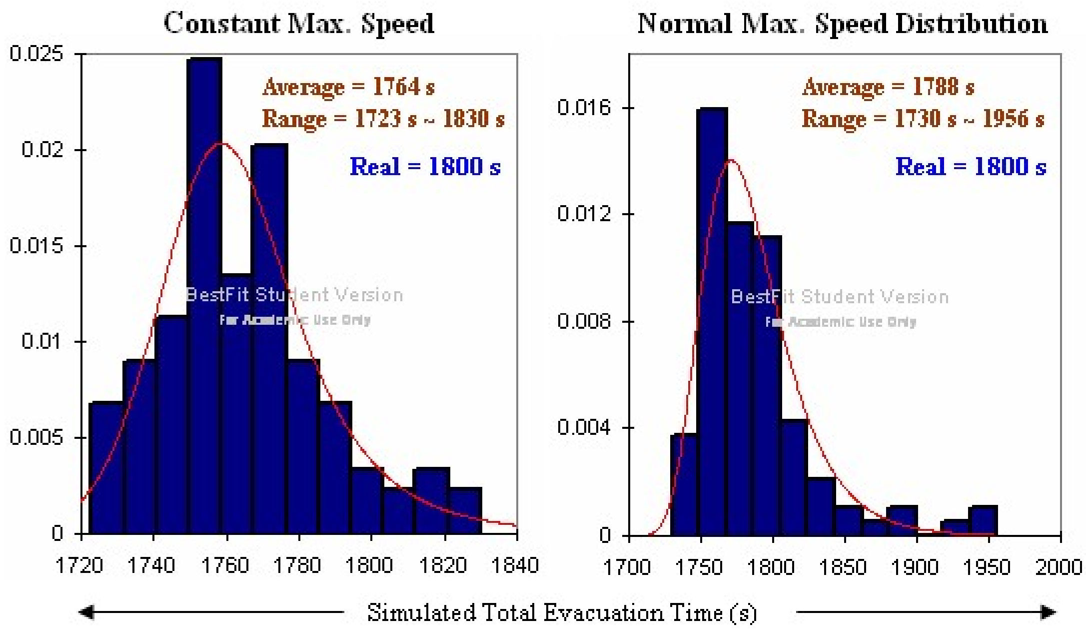


Figure 7.4: The Comparison of Simulated Results using Constant Speed and Normal Speed Distribution for both Able-bodied and Disabled Occupants.

Figure 7.4 shows the comparison of the simulated results derived from 100 batch runs in each case. Graphically, it seems that occupants with constant maximum speed produced quite a normal distributed outcome. When compared to the outcomes using constant speed, the distributed results using various maximum speeds appear to have some extreme values towards the right end, even though most of its results have covered a similar range (1730 s ~ 1830 s). Also, the mean value in both cases only has a difference of 1.3%, which is considered insignificant. It is therefore acknowledged that the use of maximum speed distribution can not only provide reasonable and realistic predictions on the total evacuation time, but also it presents some possibilities of extreme conditions (e.g. occupants with slow movements) that give a better confident range for design purposes.

On the other hand, the use of simple node configuration and the combination of MND and LOD for small% disabled appear to generate reasonable predictions on the total evacuation time for this evacuation scheme. This further validates the use of the EvacuatioNZ model on high-rise building analysis, particularly when all the occupants in every floor are evacuated.

The figure on the right is a graphical representation of the randomly simulated pre-movement times for the occupants involved using EvacuatioNZ. The shape of the simulated results verifies the effectiveness of the defined Weibull distribution, which also produced a mean similar to the real incident.

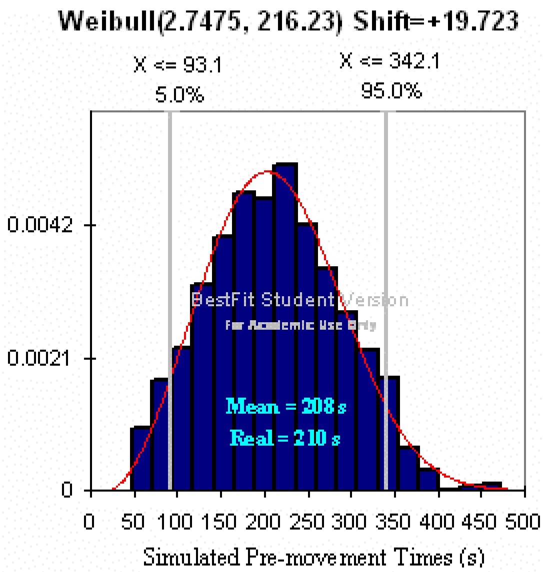


Figure 7.5: Occupants' Pre-movement Time extracted from a Random batch Run.

7.5 Conclusions

The analyses are quite straightforward with comparisons to a single value (1800 s) due to limited information acquired for this evacuation scheme. Nevertheless, these comparisons have provided some useful insights into the functional integrity of the EvacuatioNZ model. Overall, there are few findings associated with the analyses of this 21-storey office building, which are listed as follows:

- ✓ The use of normal maximum speed distribution not only could simulate reasonable results on the total evacuation time, it also provides a more confident time range that may be beneficial in fire safety design.
- ✓ It further verified the effectiveness of using simple node configuration as well as the optimal density combination suggested in Chapter 5 for small% disabled.
- ✓ The results have provided some degree of confidence for users to use the EvacuatioNZ model on high-rise building analysis when the whole building is involved in an evacuation system.

8.0 General Discussion

It is seldom that a high-rise building contains 100% disabled occupants throughout the floors. Basically, occupants in high-rise structures often contain a small percentage of disabled people, as did the 13-storey and 21-storey office buildings utilized in this research. From these analyses, it was shown that EvacuatioNZ is able to generate reasonable predictions on the total evacuation time when only a limited proportion of disabled occupants is concerned using the suggested combination of MND and LOD. Nevertheless, this suggestion only has its statement when a small percentage of disabled occupants are involved without an indication of its limit. So far from the analyses of the 21-storey office building, it can be assured that the optimal combination (MND = 2.5 ppl/m^2, LOD = 1.5 ppl/m^2) is working satisfactorily up to the involvement of 8% disabled. Further verifications may be required for other combinations of MND and LOD when there are more than 8% disabled occupants involved in an evacuation scheme.

Most high-rise building evacuation plans operate in a controlled manner with instructions that allow occupants to evacuate in a sequential pattern. EvacuatioNZ is still developing a functional feature that is able to hold a group of occupants in a certain node for a defined period, at the same time the occupants in other nodes are evacuating. Results in Chapter 6 only verify the findings from Chapter 5 regarding the usefulness of simple geometry set-up and the optimal MND and LOD combination using EvacuatioNZ. Nevertheless, results in Chapter 7 validated the use of the EvacuatioNZ model for uncontrolled high-rise building evacuation where occupants evacuated only in response to the alarm without hearing any instructions to stay at allocated places for certain periods.

8.1 Limitations of EvacuatioNZ

Ko (2003) found that EvacuatioNZ had limitations in modeling lecture theater type spaces. This functional deficiency is currently under investigation by Xiang (2006) at the University of Canterbury. Generally, the basic components within the latest EvacuatioNZ model (version 1.2) are working satisfactorily, except for some functional features that are not fully incorporated and still need to be further tested or verified (refer to Section 8.2).

Nevertheless, based on this research, some functional limitations within EvacuatioNZ were found during the sensitivity analyses of the 13-storey office building. These included the "Preferred Route" function and the "Connection" for long stairs. The model can give unrealistic results when these inputs are inappropriately used, and therefore, extra caution is needed while setting up these functions.

8.1.1 Preferred Route

EvacuatioNZ allows the user to define a certain number or group of people to evacuate through allocated pathways by applying the "Preferred Route" function in the MAP file. However, in order to make a proper simulation (i.e. errors occur under some conditions) some data inputs must be noted:

1. The connections between the starting nodes and the final exits should all be defined as "Preferred". For instance, the disabled occupants were instructed to evacuate using Stairwell D while descending to the ground floor during the 13-storey evacuation drill (refer to Section 6); therefore, all the stairway connections in Stairwell D should be defined as "Preferred". A further graphical representation is shown in Figure 8.1. Once occupants reach node B (see

Figure 8.1) they start to travel backwards since they have to follow the route that is defined as "preferred", rather than to sensibly travel towards the exits.

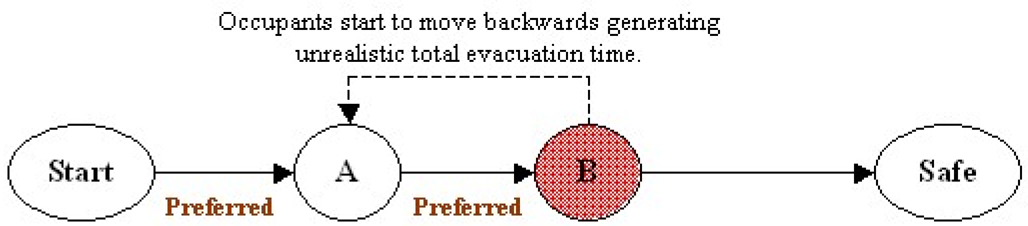


Figure 8.1: All Connections between the Starting and Safe Nodes should be defined as "Preferred".

2. As previously mentioned, the connections in the MAP file are considered as the evacuation paths for occupants to travel from one space to another. Once a certain path is defined as the "preferred route", users have to make sure that all the preferred connections have the minimum distance to the final exit. A graphical example is represented in Figure 8.2. Occupants are supposed to travel through node A and B to reach the final exit as the three connections are defined as preferred. However, in this case the occupants in node B may want to move backwards rather than travel forward to the safe node as the two connections in node B are defined as "Preferred" and going backwards to node A can give the shortest distance to the safe location (i.e. 4 m < 5 m).

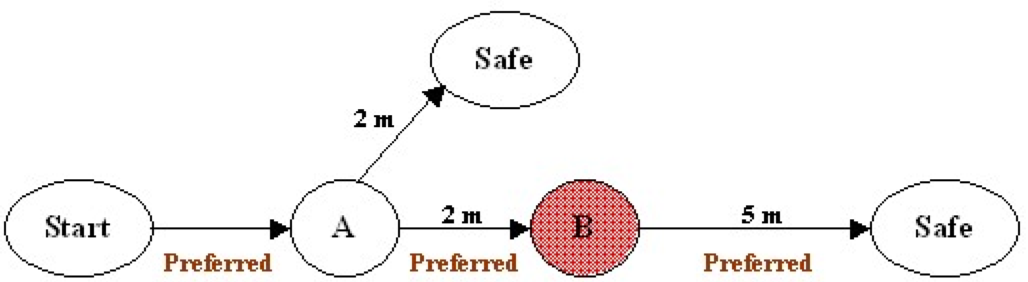


Figure 8.2: The Preferred Route should have the Minimum Distance to the Final Exit.

8.1.2 Connection for Long Stairs

The stairway between two levels is often modeled as a node at the landing followed by a connection representing the stairs (as shown in Figure 8.3). Basically, the number of occupants that can enter the landing is limited by its node capacity, which relates to the node geometry and the defined occupant density.

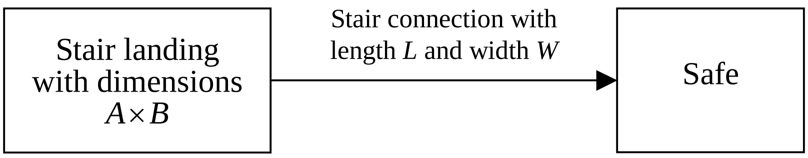


Figure 8.3: A Graphical Representation of a Stairway Connection.

The issue that arises from this representation is that there is no ‘capacity’ on the stairs to hold any people, which indicates that the maximum number of occupants allowed in the stair connection is directly related to the capacity of the stair landing. This may not be a particular problem for short stairs because the occupants quickly pass through the connection without reaching the landing capacity. However, in some circumstances when long stairs are involved, EvacuatioNZ can generate unrealistic results. In actual fact, long stairs have greater capacity to contain a reasonable amount of occupants, but the number of occupants allowed is still restricted by the node capacity of the stair landing. If we have a stairway N times longer then:

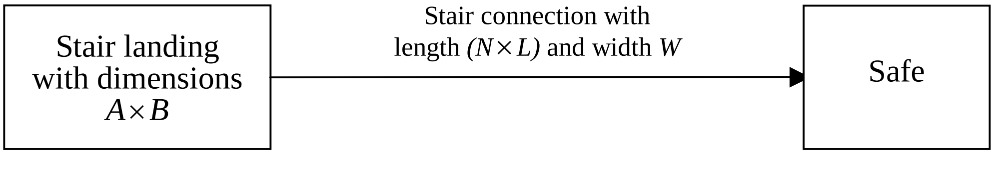


Figure 8.4: A Graphical Representation of a Long Stair Connection.

Two approaches can be utilized to resolve this limitation. However, these are only initial suggestions that may require further verifications to examine what effects they have on the simulations.

1st Approach

- Add one or more intermediate nodes into the long stairs so as to hold the number of people that exceeds the landing capacity.

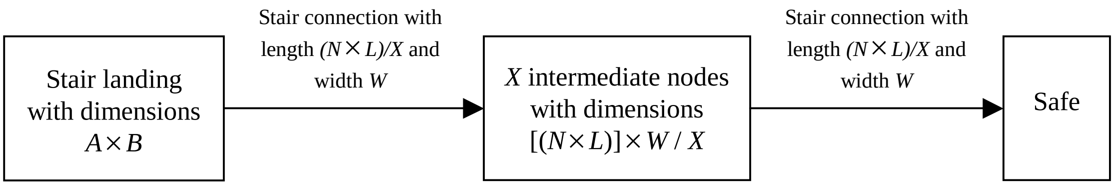


Figure 8.5: More Nodes are added in the Long Stairs.

2nd Approach

- Increase the size of the landing node to include the stairway capacity.

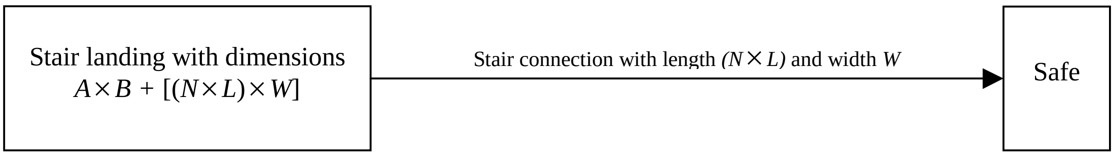


Figure 8.6: The Landing Capacity is enlarged to include the Stairway Capacity.

The 2nd approach seems to be more ideal since it requires less effort to set up each intermediate node. However, there may be a case when the increased size of the stair landing is larger than its respective floor, thus causing an unrealistic condition. Consequently, the combination of these two approaches may be an ideal solution for this limitation. Nonetheless, analyses needs to be carried out regarding these suggested approaches in order to verify their functional validity.

8.2 Further Testing

- The functional input of the lighting condition in the exit pathways is still in its infancy. The current version can only model the effects of the 4 lighting systems based on the referenced literature (Proulx et al., 1999). Further enhancement on this functional feature may be required for users to model occupants' movement under various lighting outputs or different lighting systems.

- Regarding the one-way egress function, further adjustment is essential for the preferred route function. Evacuees should egress through the defined pathways without any conflict with the shortest route function.

- Further research or improvement may be required for the connection settings between two nodes, particularly with large populations and long stairways.

- Conditional behaviour, such as the FED susceptibility and smoke blockage, can be an optional development within the EvacuatioNZ model. Thus, the program is able to simulate a wider range of prospective fire safety designs with or without the existence of fire.

- The "LOG ACTION file" is still under development for the current version. Further testing is essential before this output file can be fully established.

- In order to generalize the EvacuatioNZ model for engineering design applications, more tests should be carried out to validate the use of EvacuatioNZ model on other types of building structures. For example residential compartments, shopping malls, airport or train stations, etc.

9.0 Conclusions

- λ EvacuatioNZ incorporates the combination of maximum node density and local occupant density to account for the involvement of disabled people. Users are recommended to apply the following inputs so as to get sensible predictions on the total evacuation time:
  - ✓ MND = 2.5 ppl/m^2 LOD = 2.2 ppl/m^2 (0% disables)
  - ✓ MND = 2.5 ppl/m^2 LOD = 1.5 ppl/m^2 (3% ~ 8% disables)
  - ✓ MND = 2.5 ppl/m^2 LOD = 1.0 ppl/m^2 (100% disables)

- λ Users are able to create simple node configurations for complex geometry layout without any significant effect on the estimation of total evacuation time.

- λ The recent developments on various type pre-movement time distributions and maximum walking speed distributions are working satisfactorily. The model is able to generate reasonable results once the parameters of the distribution function are correctly entered.

- λ Overall, the EvacuatioNZ model (version 1.2) has been validated on its use for high-rise building analysis. During an evacuation scheme, users are able to obtain reasonable predictions on the total evacuation times with either the whole building or a limited number of floors being considered. Generally, setting up high-rise building evacuation systems may require more computational efforts than low-rise structures, thus causing a higher possibility of inputting errors. It is recommended that future users understand the limitations of the current model before performing a design, and are particularly cautious in the construction of MAP files.

10.0 References

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Appendix A: Component Testing Input Files

<u>FEDG Example (Pre-movement Time Distributions)</u>

- ### MAP file


```
<EvacuatioNZ_Map version="1.2" >
    <Description>FEDG Example</Description>
    <Node exists="Yes">
        <Name>Room</Name>
        <Ref>1</Ref>
        <Length>10</Length>
        <Width>10</Width>
    </Node>
    <Node exists="Yes">
        <Name>Stairs</Name>
        <Ref>2</Ref>
        <Length>10.0</Length>
        <Width>1.2</Width>
    </Node>
    <Node exists="Yes">
        <Name>Exit</Name>
        <Ref>3</Ref>
        <NodeType>Safe</NodeType>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>2</NodeRef>
        <Length>20.0</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheClimb</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>3</NodeRef>
        <Length>10.0</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
        <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
</EvacuatioNZ_Map>
```


- ### POPULATE file


```
<EvacuatioNZ_Populate version="1.2">
    <Definition>
        <People>300</People>
        <Log>no</Log>
        <Node type="single">1</Node>
        <PersonType>
            <Name>AbleBodied</Name>
            <Probability>100</Probability>
        </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```


- ### SIMULATION file


```
<EvacuatioNZ_Simulation version="1.2">
    <TimeMax>10000</TimeMax>
    <TimeStep>1</TimeStep>
    <MaxNodeDensity>2.5</MaxNodeDensity>
    <DoorFlow>Maclennan</DoorFlow>
    <OccupantDensityModel localOccupantDensity="2.2">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

- **SCENARIO file**


```
<EvacuatioNZ_Scenario version="1.2">
    <Simulations>50</Simulations>
    <DumpEvacuationTimes>Yes</DumpEvacuationTimes>
    <DumpPreEvacuationTimes>Yes</DumpPreEvacuationTimes>
    <RandomStartPosition>Yes</RandomStartPosition>
    <Files>
        <Simulation>simulation.xml</Simulation>
        <PostProcess>pp template.xml</PostProcess>
        <Populate>populate.xml</Populate>
    </Files>
</EvacuatioNZ_Scenario>
```


- **PERSON TYPE file**


```
<EvacuatioNZ_PersonType version="1.2">
    <PersonType name="AbleBodied">
        <Speed>1.5</Speed>
        <ExitBehaviour>Default</ExitBehaviour>
        <PreEvacuation type="distribution">
            <Distribution type="normal">
                <Mean>150</Mean>
                <StandardDeviation>20</StandardDeviation>
            </Distribution>
        </PreEvacuation>
    </PersonType>
</EvacuatioNZ_PersonType>
```


5 types as tested in the component testing.

- **EXIT BEHAVIOUR file**


```
<EvacuatioNZ_ExitBehaviour version="1.2">
    <ExitBehaviour name="Default">
        <ExitBehaviourType type="MinDistanceToSafe">
            <Probability>100</Probability>
        </ExitBehaviourType>
    </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```


Note: The input files for the component testing of the lighting system in the stairwells are basically the same to the input files described here except the addition of the lighting system codes in the MAP file (as described in Section 4.2) and the change of the occupant number (= 1 occupant) with no pre-movement period.

Appendix B: 21-Storey Hotel Building Input Files

- **MAP file**

<u>Simple Node Configuration</u>


```
<EvacuatioNZ_Map version="1.2">

<Description>21-storey hotel</Description>

----------------Level 21---------------------

	<Node exists="Yes">
		<Name>Level21</Name>
		<Ref>1</Ref>
		<Length>63.4</Length>
		<Width>18.6</Width>
	</Node>
	<Node exists="Yes">
		<Name>S21R</Name>
		<Ref>2</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Node exists="Yes">
		<Name>S21L</Name>
		<Ref>3</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink21R</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>25</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
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		<NodeRef>3</NodeRef>
		<Length>25</Length>
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		<Width>1.13</Width>
		</ConnectionType>
	</Connection>

----------------Level 20---------------------

	<Node exists="Yes">
		<Name>Level20</Name>
		<Ref>4</Ref>
		<Length>63.4</Length>
		<Width>18.6</Width>
	</Node>
	<Node exists="Yes">
		<Name>S20R</Name>
		<Ref>5</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Node exists="Yes">
		<Name>S20L</Name>
		<Ref>6</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Connection exists="Yes">
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		<Width>1.13</Width>
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	</Connection>
	<Connection exists="Yes">
		<Name>S2120R</Name>
		<NodeRef>2</NodeRef>
		<NodeRef>5</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
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	</Connection>
	<Connection exists="Yes">
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		<NodeRef>6</NodeRef>
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<Length>7.2</Length>
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<Riser>0.18</Riser>
</ConnectionType>
</Connection>

----------------Level 19---------------------

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----------------Level 18---------------------

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```
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        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 17---------------------

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    </Node>
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        <Name>S17R</Name>
        <Ref>14</Ref>
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    </Node>
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----------------Level 16---------------------

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        <Ref>17</Ref>
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    </Node>
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        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
```

```
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        <Name>S1716L</Name>
        <NodeRef>15</NodeRef>
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        <Riser>0.18</Riser>
        </ConnectionType>
</Connection>

----------------Level 15---------------------

<Node exists="Yes">
        <Name>Level15</Name>
        <Ref>19</Ref>
        <Length>63.4</Length>
        <Width>18.6</Width>
</Node>
<Node exists="Yes">
        <Name>S15R</Name>
        <Ref>20</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
</Node>
<Node exists="Yes">
        <Name>S15L</Name>
        <Ref>21</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
</Node>
<Connection exists="Yes">
        <Name>TheLink15R</Name>
        <NodeRef>19</NodeRef>
        <NodeRef>20</NodeRef>
        <Length>25</Length>
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        <Width>1.13</Width>
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</Connection>
<Connection exists="Yes">
        <Name>TheLink15L</Name>
        <NodeRef>19</NodeRef>
        <NodeRef>21</NodeRef>
        <Length>25</Length>
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        <Width>1.13</Width>
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</Connection>
<Connection exists="Yes">
        <Name>S1514R</Name>
        <NodeRef>17</NodeRef>
        <NodeRef>20</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>S1514L</Name>
        <NodeRef>18</NodeRef>
        <NodeRef>21</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
</Connection>

----------------Level 14---------------------

<Node exists="Yes">
        <Name>Level14</Name>
        <Ref>22</Ref>
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        <Width>18.6</Width>
</Node>
<Node exists="Yes">
        <Name>S14R</Name>
        <Ref>23</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
</Node>
<Node exists="Yes">
        <Name>S14L</Name>
        <Ref>24</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
</Node>
<Connection exists="Yes">
        <Name>TheLink14R</Name>
        <NodeRef>22</NodeRef>
        <NodeRef>23</NodeRef>
        <Length>25</Length>
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        <Width>1.13</Width>
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</Connection>
<Connection exists="Yes">
        <Name>TheLink14L</Name>
        <NodeRef>22</NodeRef>
        <NodeRef>24</NodeRef>
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        <Width>1.13</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>S1413R</Name>
        <NodeRef>20</NodeRef>
        <NodeRef>23</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
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        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1413L</Name>
        <NodeRef>21</NodeRef>
        <NodeRef>24</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 13---------------------

    <Node exists="Yes">
        <Name>Level13</Name>
        <Ref>25</Ref>
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    </Node>
    <Node exists="Yes">
        <Name>S13R</Name>
        <Ref>26</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S13L</Name>
        <Ref>27</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink13R</Name>
        <NodeRef>25</NodeRef>
        <NodeRef>26</NodeRef>
        <Length>25</Length>
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    </Connection>
    <Connection exists="Yes">
        <Name>TheLink13L</Name>
        <NodeRef>25</NodeRef>
        <NodeRef>27</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1312R</Name>
        <NodeRef>23</NodeRef>
        <NodeRef>26</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1312L</Name>
        <NodeRef>24</NodeRef>
        <NodeRef>27</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 12---------------------

    <Node exists="Yes">
        <Name>Level12</Name>
        <Ref>28</Ref>
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    </Node>
    <Node exists="Yes">
        <Name>S12R</Name>
        <Ref>29</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S12L</Name>
        <Ref>30</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink12R</Name>
        <NodeRef>28</NodeRef>
        <NodeRef>29</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink12L</Name>
        <NodeRef>28</NodeRef>
        <NodeRef>30</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1211R</Name>
        <NodeRef>26</NodeRef>
        <NodeRef>29</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
```

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            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>S1211L</Name>
            <NodeRef>27</NodeRef>
            <NodeRef>30</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
    </Connection>

----------------Level 11---------------------

    <Node exists="Yes">
            <Name>Level11</Name>
            <Ref>31</Ref>
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            <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
            <Name>S11R</Name>
            <Ref>32</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
            <Name>S11L</Name>
            <Ref>33</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
            <Name>TheLink11R</Name>
            <NodeRef>31</NodeRef>
            <NodeRef>32</NodeRef>
            <Length>25</Length>
            <ConnectionType type="Door">
            <Width>1.13</Width>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>TheLink11L</Name>
            <NodeRef>31</NodeRef>
            <NodeRef>33</NodeRef>
            <Length>25</Length>
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            <Width>1.13</Width>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>S1110R</Name>
            <NodeRef>29</NodeRef>
            <NodeRef>32</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>S1110L</Name>
            <NodeRef>30</NodeRef>
            <NodeRef>33</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
    </Connection>

----------------Level 10---------------------

    <Node exists="Yes">
            <Name>Level10</Name>
            <Ref>34</Ref>
            <Length>63.4</Length>
            <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
            <Name>S10R</Name>
            <Ref>35</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
            <Name>S10L</Name>
            <Ref>36</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
            <Name>TheLink10R</Name>
            <NodeRef>34</NodeRef>
            <NodeRef>35</NodeRef>
            <Length>25</Length>
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            <Width>1.13</Width>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>TheLink10R</Name>
            <NodeRef>34</NodeRef>
            <NodeRef>36</NodeRef>
            <Length>25</Length>
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            <Width>1.13</Width>
            </ConnectionType>
    </Connection>
    <Connection exists="Yes">
            <Name>S109R</Name>
            <NodeRef>32</NodeRef>
            <NodeRef>35</NodeRef>
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            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S109L</Name>
            <NodeRef>33</NodeRef>
            <NodeRef>36</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>

----------------Level 9---------------------

        <Node exists="Yes">
            <Name>Level9</Name>
            <Ref>37</Ref>
            <Length>63.4</Length>
            <Width>18.6</Width>
        </Node>
        <Node exists="Yes">
            <Name>S9R</Name>
            <Ref>38</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
        </Node>
        <Node exists="Yes">
            <Name>S9L</Name>
            <Ref>39</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
        </Node>
        <Connection exists="Yes">
            <Name>TheLink9R</Name>
            <NodeRef>37</NodeRef>
            <NodeRef>38</NodeRef>
            <Length>25</Length>
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            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>TheLink9L</Name>
            <NodeRef>37</NodeRef>
            <NodeRef>39</NodeRef>
            <Length>25</Length>
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            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S98R</Name>
            <NodeRef>35</NodeRef>
            <NodeRef>38</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S98L</Name>
            <NodeRef>36</NodeRef>
            <NodeRef>39</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>

----------------Level 8---------------------

        <Node exists="Yes">
            <Name>Level8</Name>
            <Ref>40</Ref>
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            <Width>18.6</Width>
        </Node>
        <Node exists="Yes">
            <Name>S8R</Name>
            <Ref>41</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
        </Node>
        <Node exists="Yes">
            <Name>S8L</Name>
            <Ref>42</Ref>
            <Length>7.2</Length>
            <Width>1.13</Width>
        </Node>
        <Connection exists="Yes">
            <Name>TheLink8R</Name>
            <NodeRef>40</NodeRef>
            <NodeRef>41</NodeRef>
            <Length>25</Length>
            <ConnectionType type="Door">
            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>TheLink8L</Name>
            <NodeRef>40</NodeRef>
            <NodeRef>42</NodeRef>
            <Length>25</Length>
            <ConnectionType type="Door">
            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S87R</Name>
```

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        <NodeRef>38</NodeRef>
        <NodeRef>41</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S87L</Name>
        <NodeRef>39</NodeRef>
        <NodeRef>42</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 7---------------------

    <Node exists="Yes">
        <Name>Level7</Name>
        <Ref>43</Ref>
        <Length>63.4</Length>
        <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
        <Name>S7R</Name>
        <Ref>44</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S7L</Name>
        <Ref>45</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink7R</Name>
        <NodeRef>43</NodeRef>
        <NodeRef>44</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink7L</Name>
        <NodeRef>43</NodeRef>
        <NodeRef>45</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S76R</Name>
        <NodeRef>41</NodeRef>
        <NodeRef>44</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S76L</Name>
        <NodeRef>42</NodeRef>
        <NodeRef>45</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 6---------------------

    <Node exists="Yes">
        <Name>Level6</Name>
        <Ref>46</Ref>
        <Length>63.4</Length>
        <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
        <Name>S6R</Name>
        <Ref>47</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S6L</Name>
        <Ref>48</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink6R</Name>
        <NodeRef>46</NodeRef>
        <NodeRef>47</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink6L</Name>
        <NodeRef>46</NodeRef>
        <NodeRef>48</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
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	<Connection exists="Yes">
		<Name>S65R</Name>
		<NodeRef>44</NodeRef>
		<NodeRef>47</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S65L</Name>
		<NodeRef>45</NodeRef>
		<NodeRef>48</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

----------------Level 5---------------------

	<Node exists="Yes">
		<Name>Level5</Name>
		<Ref>49</Ref>
		<Length>63.4</Length>
		<Width>18.6</Width>
	</Node>
	<Node exists="Yes">
		<Name>S5R</Name>
		<Ref>50</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Node exists="Yes">
		<Name>S5L</Name>
		<Ref>51</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink5R</Name>
		<NodeRef>49</NodeRef>
		<NodeRef>50</NodeRef>
		<Length>25</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink5L</Name>
		<NodeRef>49</NodeRef>
		<NodeRef>51</NodeRef>
		<Length>25</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S54R</Name>
		<NodeRef>47</NodeRef>
		<NodeRef>50</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S54L</Name>
		<NodeRef>48</NodeRef>
		<NodeRef>51</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

----------------Level 4---------------------

	<Node exists="Yes">
		<Name>Level4</Name>
		<Ref>52</Ref>
		<Length>63.4</Length>
		<Width>18.6</Width>
	</Node>
	<Node exists="Yes">
		<Name>S4R</Name>
		<Ref>53</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Node exists="Yes">
		<Name>S4L</Name>
		<Ref>54</Ref>
		<Length>7.2</Length>
		<Width>1.13</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink4R</Name>
		<NodeRef>52</NodeRef>
		<NodeRef>53</NodeRef>
		<Length>25</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink4L</Name>
		<NodeRef>52</NodeRef>
		<NodeRef>54</NodeRef>
		<Length>25</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
```

```
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S43R</Name>
        <NodeRef>50</NodeRef>
        <NodeRef>53</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S43L</Name>
        <NodeRef>51</NodeRef>
        <NodeRef>54</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 3---------------------

    <Node exists="Yes">
        <Name>Level3</Name>
        <Ref>55</Ref>
        <Length>63.4</Length>
        <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
        <Name>S3R</Name>
        <Ref>56</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S3L</Name>
        <Ref>57</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink3R</Name>
        <NodeRef>55</NodeRef>
        <NodeRef>56</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink3L</Name>
        <NodeRef>55</NodeRef>
        <NodeRef>57</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S32R</Name>
        <NodeRef>53</NodeRef>
        <NodeRef>56</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S32L</Name>
        <NodeRef>54</NodeRef>
        <NodeRef>57</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
    </Connection>

----------------Level 2---------------------

    <Node exists="Yes">
        <Name>Level2</Name>
        <Ref>58</Ref>
        <Length>63.4</Length>
        <Width>18.6</Width>
    </Node>
    <Node exists="Yes">
        <Name>S2R</Name>
        <Ref>59</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S2L</Name>
        <Ref>60</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink2R</Name>
        <NodeRef>58</NodeRef>
        <NodeRef>59</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.13</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink2L</Name>
        <NodeRef>58</NodeRef>
        <NodeRef>60</NodeRef>
        <Length>25</Length>
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```
            <ConnectionType type="Door">
            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
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            <NodeRef>56</NodeRef>
            <NodeRef>59</NodeRef>
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            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S21L</Name>
            <NodeRef>57</NodeRef>
            <NodeRef>60</NodeRef>
            <Length>7.2</Length>
            <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
            </ConnectionType>
        </Connection>

----------------Level 1---------------------

        <!-- The exit Node -->
        <Node exists="Yes">
            <Name>Exit</Name>
            <Ref>61</Ref>
            <NodeType>Safe</NodeType>
            <!-- dimensions are not required for a
safe Node -->
        </Node>
        <Connection exists="Yes">
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            <NodeRef>59</NodeRef>
            <NodeRef>61</NodeRef>
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            <Width>1.13</Width>
            </ConnectionType>
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        <Connection exists="Yes">
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            <NodeRef>60</NodeRef>
            <NodeRef>61</NodeRef>
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            <ConnectionType type="Door">
            <Width>1.13</Width>
            </ConnectionType>
        </Connection>
</EvacuatioNZ_Map>
```


<u>Complex Node Configuration</u>


```
<EvacuatioNZ_Map version="1.01">

<Description>21-storey hotel</Description>

----------------Level 21----------------
------Room------

        <Node exists="Yes">
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        <Node exists="Yes">
            <Name>21R2</Name>
            <Ref>2</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
        </Node>
        <Node exists="Yes">
            <Name>21R3</Name>
            <Ref>3</Ref>

            <Length>8.3</Length>
            <Width>3.9</Width>
        </Node>
        <Node exists="Yes">
            <Name>21R4</Name>
            <Ref>4</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
        </Node>
        <Node exists="Yes">
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            <Ref>5</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
        </Node>
        <Node exists="Yes">
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            <Ref>6</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
        </Node>
        <Node exists="Yes">
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            <Ref>7</Ref>
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</Node>
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</Node>
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<Width>3.9</Width>
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<Node exists="Yes">
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<Node exists="Yes">
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<Ref>18</Ref>
<Length>8.3</Length>
<Width>3.9</Width>
</Node>
<Node exists="Yes">
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<Ref>19</Ref>
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<Width>3.9</Width>
</Node>
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<Name>21R20</Name>
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<Width>3.9</Width>
</Node>
<Node exists="Yes">
<Name>21R21</Name>
<Ref>21</Ref>
<Length>8.3</Length>
<Width>3.9</Width>
</Node>
<Node exists="Yes">
<Name>21R22</Name>
<Ref>22</Ref>
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<Width>8.3</Width>
</Node>

------Corridor------

<Node exists="Yes">
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<Ref>23</Ref>
<Length>49</Length>
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</Node>

------Stairway------

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<Width>1.13</Width>
</Node>
<Node exists="Yes">
<Name>S21L</Name>
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<Width>1.13</Width>

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	</Node>

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		<NodeRef>23</NodeRef>
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		<ConnectionType type="Door">
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		<NodeRef>23</NodeRef>
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		<NodeRef>23</NodeRef>
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	<Connection exists="Yes">
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		<NodeRef>23</NodeRef>
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	<Connection exists="Yes">
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		<NodeRef>23</NodeRef>
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	<Connection exists="Yes">
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		<NodeRef>23</NodeRef>
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		<NodeRef>23</NodeRef>
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        <Width>1.10</Width>
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        <Width>1.0</Width>
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        <NodeRef>23</NodeRef>
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        <Width>1.0</Width>
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<Connection exists="Yes">
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        <NodeRef>23</NodeRef>
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        <Width>1.10</Width>
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        <NodeRef>22</NodeRef>
        <NodeRef>23</NodeRef>
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        <Width>1.0</Width>
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<Connection exists="Yes">
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        <NodeRef>24</NodeRef>
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        <Name>TheLink21L</Name>
        <NodeRef>23</NodeRef>
        <NodeRef>25</NodeRef>
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----------------Level 20----------------
------Room------

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<Name>20R3</Name>
<Ref>28</Ref>
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<Width>3.9</Width>
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<Node exists="Yes">
<Name>20R4</Name>
<Ref>29</Ref>
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<Width>3.9</Width>
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<Name>20R5</Name>
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<Name>20R7</Name>
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<Ref>36</Ref>
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<Name>20R12</Name>
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<Node exists="Yes">
<Name>20R16</Name>
<Ref>41</Ref>
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<Name>20R17</Name>
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</Node>
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<Name>20R18</Name>
<Ref>43</Ref>
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<Name>20R21</Name>
<Ref>46</Ref>

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<Name>20R22</Name>
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------Corridor------

<Node exists="Yes">
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------Stairway------

<Node exists="Yes">
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</Node>
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<Ref>50</Ref>
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<Width>1.13</Width>
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------Connections------

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</Connection>
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	<NodeRef>36</NodeRef>
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	<Width>1.0</Width>
	</ConnectionType>
</Connection>
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	<Name>20RC12</Name>
	<NodeRef>37</NodeRef>
	<NodeRef>48</NodeRef>
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	<Width>1.10</Width>
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	<NodeRef>38</NodeRef>
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	<NodeRef>40</NodeRef>
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	<Name>20RC16</Name>
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</Connection>
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	<NodeRef>42</NodeRef>
	<NodeRef>48</NodeRef>
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	<Width>1.10</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>20RC18</Name>
	<NodeRef>43</NodeRef>
	<NodeRef>48</NodeRef>
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	<Width>1.0</Width>
	</ConnectionType>
</Connection>
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	<NodeRef>44</NodeRef>
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	<Width>1.10</Width>
	</ConnectionType>
</Connection>
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	<Name>20RC20</Name>
	<NodeRef>45</NodeRef>
	<NodeRef>48</NodeRef>
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	<Width>1.0</Width>
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</Connection>
<Connection exists="Yes">
	<Name>20RC21</Name>
	<NodeRef>46</NodeRef>
	<NodeRef>48</NodeRef>
	<Length>4.7</Length>
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	<Width>1.10</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>20RC22</Name>
	<NodeRef>47</NodeRef>
	<NodeRef>48</NodeRef>
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	<Width>1.0</Width>
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```
			</ConnectionType>
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			<NodeRef>49</NodeRef>
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		<Connection exists="Yes">
			<Name>TheLink20L</Name>
			<NodeRef>48</NodeRef>
			<NodeRef>50</NodeRef>
			<Length>25</Length>
			<ConnectionType type="Door">
			<Width>1.13</Width>
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		<Connection exists="Yes">
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			<NodeRef>24</NodeRef>
			<NodeRef>49</NodeRef>
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			<Riser>0.18</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S2120L</Name>
			<NodeRef>25</NodeRef>
			<NodeRef>50</NodeRef>
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			<ConnectionType type="Stairs">
			<Tread>0.28</Tread>
			<Riser>0.18</Riser>
			</ConnectionType>
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----------------Level 19----------------
------Room------

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			<Ref>57</Ref>
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			<Ref>61</Ref>
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			<Ref>62</Ref>
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------Corridor------

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------Stairway------

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	</Node>
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		<Ref>75</Ref>
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		<NodeRef>73</NodeRef>
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	<NodeRef>75</NodeRef>
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	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
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----------------Level 18----------------
------Room------

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------Corridor------

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------Stairway------

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		<Riser>0.18</Riser>
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		<ConnectionType type="Stairs">
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----------------Level 17----------------
------Room------

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------Corridor------

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------Stairway------

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    <NodeRef>125</NodeRef>
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    <Tread>0.28</Tread>
    <Riser>0.18</Riser>
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----------------Level 16----------------
------Room------

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    <Ref>129</Ref>
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<Node exists="Yes">
        <Name>16R21</Name>
        <Ref>146</Ref>
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------Corridor------

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------Stairway------
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----------------Level 15----------------
------Room------

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------Corridor------

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------Stairway------

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----------------Level 14----------------
------Room------

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------Corridor------

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------Stairway------

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------Connections------

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----------------Level 13----------------

------Room------

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        <Ref>222</Ref>
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------Corridor------

    <Node exists="Yes">
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------Stairway------

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    <Node exists="Yes">
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        <Ref>225</Ref>
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------Connections------

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<Connection exists="Yes">
    <Name>13RC6</Name>
    <NodeRef>206</NodeRef>
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<Name>13RC15</Name>
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		<NodeRef>223</NodeRef>
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		<Riser>0.18</Riser>
		</ConnectionType>
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		<NodeRef>225</NodeRef>
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		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

----------------Level 12----------------
------Room------

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		<Ref>232</Ref>
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        <Name>12R21</Name>
        <Ref>246</Ref>
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------Corridor------

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------Stairway------

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</Node>
<Node exists="Yes">
        <Name>S12L</Name>
        <Ref>250</Ref>
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        <Width>1.13</Width>
</Node>

------Connections------

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<NodeRef>231</NodeRef>
<NodeRef>248</NodeRef>
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		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S1312L</Name>
		<NodeRef>225</NodeRef>
		<NodeRef>250</NodeRef>
		<Length>7.2</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
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</ConnectionType>
</Connection>

----------------Level 11----------------
------Room------

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<Name>11R1</Name>
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<Node exists="Yes">
<Name>11R8</Name>
<Ref>258</Ref>
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<Name>11R9</Name>
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<Name>11R19</Name>

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    </Node>
    <Node exists="Yes">
        <Name>11R21</Name>
        <Ref>271</Ref>
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    </Node>
    <Node exists="Yes">
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```


------Corridor------


```
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    </Node>
```


------Stairway------


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    <Node exists="Yes">
        <Name>S11L</Name>
        <Ref>275</Ref>
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```


------Connections------


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        <NodeRef>251</NodeRef>
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----------------Level 10----------------
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------Corridor------

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----------------Level 9----------------
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------Corridor------

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------Stairway------

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----------------Level 8----------------
------Room------

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------Corridor------

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------Stairway------

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------Connections------

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----------------Level 7----------------
Room------

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------Corridor------

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------Stairway------

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----------------Level 6----------------
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------Corridor------

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------Stairway------

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----------------Level 5----------------
Room------

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------Corridor------

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------Stairway------

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------Corridor------

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------Stairway------

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----------------Level 3----------------
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------Corridor------

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------Stairway------

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----------------Level 2----------------

Room------


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      <Node exists="Yes">
            <Name>2R6</Name>
            <Ref>481</Ref>
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      <Node exists="Yes">
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            <Ref>483</Ref>
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            <Width>3.9</Width>
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            <Ref>484</Ref>
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            <Ref>486</Ref>
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            <Ref>488</Ref>
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            <Width>3.9</Width>
      </Node>
      <Node exists="Yes">
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            <Ref>489</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
      </Node>
      <Node exists="Yes">
            <Name>2R15</Name>
            <Ref>490</Ref>
            <Length>8.3</Length>
            <Width>3.9</Width>
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      <Node exists="Yes">
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            <Ref>491</Ref>
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      <Node exists="Yes">
```

```
        <Name>2R17</Name>
        <Ref>492</Ref>
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        <Width>8.3</Width>
    </Node>

------Corridor------

    <Node exists="Yes">
        <Name>C2</Name>
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        <Length>49</Length>
        <Width>1.9</Width>
    </Node>

------Stairway------

    <Node exists="Yes">
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        <Ref>494</Ref>
        <Length>7.2</Length>
        <Width>1.13</Width>
    </Node>
    <Node exists="Yes">
        <Name>S2L</Name>
        <Ref>495</Ref>
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        <Width>1.13</Width>
    </Node>

------Connections------

    <Connection exists="Yes">
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        <NodeRef>493</NodeRef>
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        <NodeRef>493</NodeRef>
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        <NodeRef>493</NodeRef>
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    <Connection exists="Yes">
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        <NodeRef>493</NodeRef>
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        <Width>1.10</Width>
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    <Connection exists="Yes">
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        <NodeRef>480</NodeRef>
        <NodeRef>493</NodeRef>
        <Length>4.7</Length>
        <ConnectionType type="Door">
        <Width>1.0</Width>
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    <Connection exists="Yes">
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        <NodeRef>493</NodeRef>
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    <Connection exists="Yes">
        <Name>2RC7</Name>
        <NodeRef>482</NodeRef>
        <NodeRef>493</NodeRef>
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        <Width>1.0</Width>
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    <Connection exists="Yes">
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        <NodeRef>483</NodeRef>
        <NodeRef>493</NodeRef>
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    <Connection exists="Yes">
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        <Width>1.0</Width>
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    </Connection>
    <Connection exists="Yes">
        <Name>2RC10</Name>
        <NodeRef>485</NodeRef>
```

```
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<Connection exists="Yes">
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        <NodeRef>493</NodeRef>
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        <Width>1.10</Width>
```

```
        </ConnectionType>
</Connection>
<Connection exists="Yes">
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        <NodeRef>493</NodeRef>
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</Connection>

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</Connection>
<Connection exists="Yes">
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        <NodeRef>493</NodeRef>
        <NodeRef>495</NodeRef>
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<Connection exists="Yes">
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        <ConnectionType type="Stairs">
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        <Riser>0.18</Riser>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>S32L</Name>
        <NodeRef>475</NodeRef>
        <NodeRef>495</NodeRef>
        <Length>7.2</Length>
        <ConnectionType type="Stairs">
        <Tread>0.28</Tread>
        <Riser>0.18</Riser>
        </ConnectionType>
</Connection>

----------------Level 1----------------

<!-- The exit Node -->
<Node exists="Yes">
        <Name>Exit</Name>
        <Ref>496</Ref>
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		<NodeType>Safe</NodeType>
		<!-- dimensions are not required for a safe Node -->
	</Node>
	<Connection exists="Yes">
		<Name>TheLink1R</Name>
		<NodeRef>494</NodeRef>
		<NodeRef>496</NodeRef>
		<Length>1</Length>
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		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink1L</Name>
		<NodeRef>495</NodeRef>
		<NodeRef>496</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>1.13</Width>
		</ConnectionType>
	</Connection>
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- **POPULATE file**


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<EvacuatioNZ_Populate version="1.2">

--------Level 21------------

	<Definition>
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			<Probability>97</Probability>
		</PersonType>
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			<Probability>3</Probability>
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			<Probability>97</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
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			<Probability>97</Probability>
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		<PersonType>
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		<PersonType>
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		<PersonType>
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```

```
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		</Definition>

--------Level 20------------

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				<Probability>97</Probability>
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		<Definition>
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				<Probability>97</Probability>
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			<PersonType>
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--------Level 19------------

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				<Probability>97</Probability>
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--------Level 18------------

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			<Probability>97</Probability>
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--------Level 17------------

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--------Level 16------------

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			<Probability>97</Probability>
```

```
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--------Level 15------------

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			<Probability>97</Probability>
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			<Probability>3</Probability>
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			<Probability>97</Probability>
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			<Probability>97</Probability>
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		<Log>no</Log>
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			<Probability>97</Probability>
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		<PersonType>
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--------Level 14------------

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		<Log>no</Log>
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			<Probability>97</Probability>
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		<PersonType>
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			<Probability>3</Probability>
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		<Log>no</Log>
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			<Probability>97</Probability>
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		<PersonType>
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--------Level 13------------

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			<Probability>97</Probability>
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		<Log>no</Log>
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		<PersonType>
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--------Level 12------------

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		<Log>no</Log>
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			<Probability>97</Probability>
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		<PersonType>
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		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
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            <Probability>97</Probability>
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            <Probability>3</Probability>
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            <Probability>97</Probability>
        </PersonType>
        <PersonType>
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            <Probability>97</Probability>
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--------Level 11------------


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            <Probability>97</Probability>
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            <Probability>97</Probability>
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        <PersonType>
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            <Probability>97</Probability>
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            <Probability>97</Probability>
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--------Level 10------------

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--------Level 9------------

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--------Level 8------------

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			<Probability>3</Probability>
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--------Level 7------------

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		<PersonType>
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			<Probability>3</Probability>
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		<Log>no</Log>
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--------Level 6------------

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		<Log>no</Log>
		<Node type="range">377 385</Node>
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			<Probability>97</Probability>
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		<PersonType>
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			<Probability>97</Probability>
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			<Probability>3</Probability>
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	<Definition>
		<People>2</People>
		<Log>no</Log>
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			<Name>Disable</Name>
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--------Level 5------------
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	<Definition>
		<People>2</People>
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			<Probability>97</Probability>
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		<PersonType>
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			<Probability>3</Probability>
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			<Probability>97</Probability>
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		<PersonType>
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			<Probability>3</Probability>
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			<Probability>97</Probability>
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		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
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		<Log>no</Log>
		<Node type="range">413 421</Node>
		<PersonType>
```

```
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            <Probability>97</Probability>
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        <PersonType>
            <Name>Disable</Name>
            <Probability>3</Probability>
        </PersonType>
    </Definition>
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            <Probability>97</Probability>
        </PersonType>
        <PersonType>
            <Name>Disable</Name>
            <Probability>3</Probability>
        </PersonType>
    </Definition>

--------Level 4------------

    <Definition>
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        <Log>no</Log>
        <Node type="single">426</Node>
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            <Probability>97</Probability>
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        <PersonType>
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        <Node type="range">427 435</Node>
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            <Probability>97</Probability>
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        <PersonType>
            <Name>Disable</Name>
            <Probability>3</Probability>
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            <Probability>97</Probability>
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        <PersonType>
            <Name>Disable</Name>
            <Probability>3</Probability>
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            <Probability>97</Probability>
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            <Probability>3</Probability>
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            <Probability>97</Probability>
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            <Name>Disable</Name>
            <Probability>3</Probability>
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            <Probability>97</Probability>
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            <Name>Disable</Name>
            <Probability>3</Probability>
        </PersonType>
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--------Level 3------------

    <Definition>
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            <Probability>97</Probability>
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            <Name>Disable</Name>
            <Probability>3</Probability>
```

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			<Probability>97</Probability>
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		<PersonType>
			<Name>Disable</Name>
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			<Probability>97</Probability>
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		<PersonType>
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		<PersonType>
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			<Probability>3</Probability>
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--------Level 2------------

	<Definition>
		<People>2</People>
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			<Probability>97</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>5</People>
		<Log>no</Log>
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			<Probability>97</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
		</PersonType>
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	<Definition>
		<People>2</People>
		<Log>no</Log>
		<Node type="range">482 492</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>97</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>3</Probability>
		</PersonType>
	</Definition>

</EvacuatioNZ_Populate>
```

- **SIMULATION file**

Relating to the % of disabled occupants involved


```
<EvacuatioNZ_Simulation version="1.2">
    <TimeMax>2000</TimeMax>
    <TimeStep>1</TimeStep>
    <MaxNodeDensity>2.5</MaxNodeDensity>
    <DoorFlow>Maclennan</DoorFlow>
    <OccupantDensityModel localOccupantDensity="1.5">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


- **SCENARIO file**


```
<EvacuatioNZ_Scenario version="1.2">
    <Simulations>100</Simulations>
    <DumpEvacuationTimes>Yes</DumpEvacuationTimes>
    <RandomStartPosition>Yes</RandomStartPosition>
    <Files>
        <Simulation>simulation.xml</Simulation>
        <PostProcess>pp template.xml</PostProcess>
        <Populate>populate.xml</Populate>
    </Files>
</EvacuatioNZ_Scenario>
```


- **PERSON TYPE file**


```
<EvacuatioNZ_PersonType version="1.2">
    <PersonType name="AbleBodied">
        <Speed>1.5</Speed>
        <ExitBehaviour>Default</ExitBehaviour>
    </PersonType>
    <PersonType name="Disable">
        <Speed>0.7</Speed>
        <ExitBehaviour>Default</ExitBehaviour>
    </PersonType>
</EvacuatioNZ_PersonType>
```


- **EXIT BEHAVIOUR file**


```
<EvacuatioNZ_ExitBehaviour version="1.2">
    <ExitBehaviour name="Default">
        <ExitBehaviourType type="MinDistanceToSafe">
            <Probability>100</Probability>
        </ExitBehaviourType>
    </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

Appendix C: 13-Storey Office Building Input Files

- **MAP file**


```
<EvacuatioNZ_Map version="1.2">

<Description>Trial 2</Description>

----------------Level 11---------------------

    <Node exists="Yes">
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        <Name>SA11</Name>
        <Ref>2</Ref>
        <Length>9.7</Length>
        <Width>1.1</Width>
    </Node>
    <Node exists="Yes">
        <Name>SB11</Name>
        <Ref>3</Ref>
        <Length>9.7</Length>
        <Width>1.1</Width>
    </Node>
    <Node exists="Yes">
        <Name>SC11</Name>
        <Ref>4</Ref>
        <Length>9.7</Length>
        <Width>1.1</Width>
    </Node>
    <Node exists="Yes">
        <Name>SD11</Name>
        <Ref>5</Ref>
        <Length>9.7</Length>
        <Width>1.1</Width>
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        <Name>TheLink11A</Name>
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        <NodeRef>2</NodeRef>
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        <Width>1.1</Width>
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        <Name>TheLink11B</Name>
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        <NodeRef>3</NodeRef>
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    <Connection exists="Yes">
        <Name>TheLink11C</Name>
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        <Width>1.1</Width>
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    <Connection exists="Yes">
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        <NodeRef>5</NodeRef>
        <Length>25</Length>
        <ConnectionType type="Door">
        <Width>1.1</Width>
        </ConnectionType>
    </Connection>

----------------Level 10---------------------

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    <Node exists="Yes">
        <Name>SA10</Name>
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        <Length>9.7</Length>
        <Width>1.1</Width>
    </Node>
    <Node exists="Yes">
        <Name>SB10</Name>
        <Ref>8</Ref>
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        <Width>1.1</Width>
    </Node>
    <Node exists="Yes">
        <Name>SC10</Name>
        <Ref>9</Ref>
        <Length>9.7</Length>
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    <Node exists="Yes">
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        <Ref>10</Ref>
```

```
        <Length>9.7</Length>
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----------------Level 9---------------------

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        <Name>SB9</Name>
        <Ref>13</Ref>
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        <Name>SC9</Name>
        <Ref>14</Ref>
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</Node>
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        <Name>SD9</Name>
        <Ref>15</Ref>
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----------------Level 8---------------------

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```
			<Riser>0.18</Riser>
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		</Connection>
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		</Node>
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		</Node>
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			<Riser>0.18</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>SD87</Name>
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			<Tread>0.28</Tread>
			<Riser>0.18</Riser>
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	----------------Level 6---------------------

		<Node exists="Yes">
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		</Node>
		<Node exists="Yes">
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			<Ref>25</Ref>
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		</Node>
		<Node exists="Yes">
			<Name>SC6</Name>
			<Ref>26</Ref>
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		</Node>
		<Node exists="Yes">
			<Name>SD6</Name>
			<Ref>27</Ref>
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```

```
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                <Riser>0.18</Riser>
                </ConnectionType>
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        <Connection exists="Yes">
                <Name>SB76</Name>
                <NodeRef>21</NodeRef>
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                <ConnectionType type="Stairs">
                <Tread>0.28</Tread>
                <Riser>0.18</Riser>
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        </Connection>
        <Connection exists="Yes">
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                <NodeRef>22</NodeRef>
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                <Length>9.7</Length>
                <ConnectionType type="Stairs">
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                <Riser>0.18</Riser>
                </ConnectionType>
        </Connection>
        <Connection exists="Yes">
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                <NodeRef>23</NodeRef>
                <NodeRef>27</NodeRef>
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                <Riser>0.18</Riser>
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        </Connection>

----------------Level 5---------------------

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        <Node exists="Yes">
                <Name>SB5</Name>
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        </Node>
        <Node exists="Yes">
                <Name>SC5</Name>
                <Ref>30</Ref>
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                <Width>1.1</Width>
        </Node>
        <Node exists="Yes">
                <Name>SD5</Name>
                <Ref>31</Ref>
                <Length>9.7</Length>
                <Width>1.1</Width>
        </Node>
        <Connection exists="Yes">
                <Name>SA65</Name>
                <NodeRef>24</NodeRef>
                <NodeRef>28</NodeRef>
                <Length>9.7</Length>
                <ConnectionType type="Stairs">
                <Tread>0.28</Tread>
                <Riser>0.18</Riser>
                </ConnectionType>
        </Connection>
        <Connection exists="Yes">
                <Name>SB65</Name>
                <NodeRef>25</NodeRef>
                <NodeRef>29</NodeRef>
                <Length>9.7</Length>
                <ConnectionType type="Stairs">
                <Tread>0.28</Tread>
                <Riser>0.18</Riser>
                </ConnectionType>
        </Connection>
        <Connection exists="Yes">
                <Name>SC65</Name>
                <NodeRef>26</NodeRef>
                <NodeRef>30</NodeRef>
                <Length>9.7</Length>
                <ConnectionType type="Stairs">
                <Tread>0.28</Tread>
                <Riser>0.18</Riser>
                </ConnectionType>
        </Connection>
        <Connection exists="Yes">
                <Name>SD65</Name>
                <NodeRef>27</NodeRef>
                <NodeRef>31</NodeRef>
                <Length>9.7</Length>
                <ConnectionType type="Stairs">
                <Tread>0.28</Tread>
                <Riser>0.18</Riser>
                </ConnectionType>
        </Connection>

----------------Level 4---------------------

        <Node exists="Yes">
                <Name>SA4</Name>
                <Ref>32</Ref>
                <Length>9.7</Length>
                <Width>1.1</Width>
```

```
</Node>
<Node exists="Yes">
	<Name>SB4</Name>
	<Ref>33</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Node exists="Yes">
	<Name>SC4</Name>
	<Ref>34</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Node exists="Yes">
	<Name>SD4</Name>
	<Ref>35</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Connection exists="Yes">
	<Name>SA54</Name>
	<NodeRef>28</NodeRef>
	<NodeRef>32</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>SB54</Name>
	<NodeRef>29</NodeRef>
	<NodeRef>33</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>SC54</Name>
	<NodeRef>30</NodeRef>
	<NodeRef>34</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>SD54</Name>
	<NodeRef>31</NodeRef>
	<NodeRef>35</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>

----------------Level 3---------------------

<Node exists="Yes">
	<Name>SA3</Name>
	<Ref>36</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Node exists="Yes">
	<Name>SB3</Name>
	<Ref>37</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Node exists="Yes">
	<Name>SC3</Name>
	<Ref>38</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Node exists="Yes">
	<Name>SD3</Name>
	<Ref>39</Ref>
	<Length>9.7</Length>
	<Width>1.1</Width>
</Node>
<Connection exists="Yes">
	<Name>SA43</Name>
	<NodeRef>32</NodeRef>
	<NodeRef>36</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>SB43</Name>
	<NodeRef>33</NodeRef>
	<NodeRef>37</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>SC43</Name>
	<NodeRef>34</NodeRef>
	<NodeRef>38</NodeRef>
	<Length>9.7</Length>
	<ConnectionType type="Stairs">
	<Tread>0.28</Tread>
	<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
```

```
	<Connection exists="Yes">
		<Name>SD43</Name>
		<NodeRef>35</NodeRef>
		<NodeRef>39</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

----------------Level 2---------------------

	<Node exists="Yes">
		<Name>SA2</Name>
		<Ref>40</Ref>
		<Length>9.7</Length>
		<Width>1.1</Width>
	</Node>
	<Node exists="Yes">
		<Name>SB2</Name>
		<Ref>41</Ref>
		<Length>9.7</Length>
		<Width>1.1</Width>
	</Node>
	<Node exists="Yes">
		<Name>SC2</Name>
		<Ref>42</Ref>
		<Length>9.7</Length>
		<Width>1.1</Width>
	</Node>
	<Node exists="Yes">
		<Name>SD2</Name>
		<Ref>43</Ref>
		<Length>9.7</Length>
		<Width>1.1</Width>
	</Node>
	<Connection exists="Yes">
		<Name>SA32</Name>
		<NodeRef>36</NodeRef>
		<NodeRef>40</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SB32</Name>
		<NodeRef>37</NodeRef>
		<NodeRef>41</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SC32</Name>
		<NodeRef>38</NodeRef>
		<NodeRef>42</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SD32</Name>
		<NodeRef>39</NodeRef>
		<NodeRef>43</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

----------------Level 1---------------------

	<!-- The exit Node -->
	<Node exists="Yes">
		<Name>Exit</Name>
		<Ref>44</Ref>
		<NodeType>Safe</NodeType>
		<!-- dimensions are not required for a safe Node -->
	</Node>
	<Connection exists="Yes">
		<Name>SA21</Name>
		<NodeRef>40</NodeRef>
		<NodeRef>44</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SB21</Name>
		<NodeRef>41</NodeRef>
		<NodeRef>44</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SC21</Name>
		<NodeRef>42</NodeRef>
		<NodeRef>44</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
```

```
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>SD21</Name>
		<NodeRef>43</NodeRef>
		<NodeRef>44</NodeRef>
		<Length>9.7</Length>
		<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
		</ConnectionType>
	</Connection>

</EvacuatioNZ_Map>
```


- **POPULATE file**


```
<EvacuatioNZ_Populate version="1.2">


--------Level 11------------

	<Definition>
		<People>131</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>94</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>6</Probability>
		</PersonType>
	</Definition>

--------Level 10------------

	<Definition>
		<People>131</People>
		<Log>no</Log>
		<Node type="single">6</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>94</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>6</Probability>
		</PersonType>
	</Definition>

--------Level 9------------

	<Definition>
		<People>130</People>
		<Log>no</Log>
		<Node type="single">11</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>94</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>6</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```


- **SIMULATION file**


```
<EvacuatioNZ_Simulation version="1.2">
	<TimeMax>2000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.5</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="1.5">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

- **SCENARIO file**


```xml
<EvacuatioNZ_Scenario version="1.2">
    <Simulations>100</Simulations>
    <DumpEvacuationTimes>Yes</DumpEvacuationTimes>
    <DumpPreEvacuationTimes>Yes</DumpPreEvacuationTimes>
    <RandomStartPosition>Yes</RandomStartPosition>
    <Files>
        <Simulation>simulation.xml</Simulation>
        <PostProcess>pp template.xml</PostProcess>
        <Populate>populate.xml</Populate>
    </Files>
</EvacuatioNZ_Scenario>
```


- **PERSON TYPE file**

<u>Scenario 1</u>


```xml
<EvacuatioNZ_PersonType version="1.2">
<PersonType name="AbleBodied">
    <Speed>1.35</Speed>
    <ExitBehaviour>Default</ExitBehaviour>
    <PreEvacuation type="distribution">
    <Distribution type="AbleBodied">
    <Mean>180</Mean>
    <StandardDeviation>150</StandardDeviation>
    </Distribution>
    </PreEvacuation>
</PersonType>
    <PersonType name="Disable">
    <Speed>1.0</Speed>
    <ExitBehaviour>Default</ExitBehaviour>
    <PreEvacuation type="distribution">
    <Distribution type="normal">
    <Mean>180</Mean>
    <StandardDeviation>150</StandardDeviation>
    </Distribution>
    </PreEvacuation>
</PersonType>
</EvacuatioNZ_PersonType>
```


<u>Scenario 2</u>


```xml
<EvacuatioNZ_PersonType version="1.2">
<PersonType name="AbleBodied">
    <Speed>1.35</Speed>
    <ExitBehaviour>Default</ExitBehaviour>
    <PreEvacuation type="distribution">
    <Distribution type="uniform">
    <Min>229</Min>
    <Max>301</Max>
    </Distribution>
    </PreEvacuation>
</PersonType>
<PersonType name="Disable">
    <Speed>1.0</Speed>
    <ExitBehaviour>Preferred</ExitBehaviour>
    <PreEvacuation type="distribution">
        <Distribution type="uniform">
            <Min>374</Min>
            <Max>662</Max>
        </Distribution>
    </PreEvacuation>
</PersonType>
</EvacuatioNZ_PersonType>
```


- **EXIT BEHAVIOUR file**


```xml
<EvacuatioNZ_ExitBehaviour version="1.2">
    <ExitBehaviour name="Default">
        <ExitBehaviourType type="MinDistanceToSafe">
            <Probability>100</Probability>
        </ExitBehaviourType>
    </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

Appendix D: 21-Storey Office Building Input Files

- **MAP file**


```
<EvacuatioNZ_Map version="1.2">

<Description>Trial 1</Description>

----------------Level 21---------------------

	<Node exists="Yes">
		<Name>Level21</Name>
		<Ref>1</Ref>
		<Length>30</Length>
		<Width>25</Width>
	</Node>
	<Node exists="Yes">
		<Name>S21R</Name>
		<Ref>2</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Node exists="Yes">
		<Name>S21L</Name>
		<Ref>3</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink21R</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink21L</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>3</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>

----------------Level 20---------------------

	<Node exists="Yes">
		<Name>Level20</Name>
		<Ref>4</Ref>
		<Length>30</Length>
		<Width>25</Width>
	</Node>
<Node exists="Yes">
	<Name>S20R</Name>
	<Ref>5</Ref>
	<Length>7.3</Length>
	<Width>1.06</Width>
</Node>
<Node exists="Yes">
	<Name>S20L</Name>
	<Ref>6</Ref>
	<Length>7.3</Length>
	<Width>1.06</Width>
</Node>
<Connection exists="Yes">
	<Name>TheLink20R</Name>
	<NodeRef>4</NodeRef>
	<NodeRef>5</NodeRef>
	<Length>1</Length>
	<ConnectionType type="Door">
	<Width>0.8</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>TheLink20L</Name>
	<NodeRef>4</NodeRef>
	<NodeRef>6</NodeRef>
	<Length>1</Length>
	<ConnectionType type="Door">
	<Width>0.8</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>S2120R</Name>
	<NodeRef>2</NodeRef>
	<NodeRef>5</NodeRef>
	<Length>7.3</Length>
	<ConnectionType type="Stairs">
	<Tread>0.255</Tread>
	<Riser>0.185</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>S2120L</Name>
	<NodeRef>3</NodeRef>
	<NodeRef>6</NodeRef>
	<Length>7.3</Length>
	<ConnectionType type="Stairs">
	<Tread>0.255</Tread>
	<Riser>0.185</Riser>
	</ConnectionType>
</Connection>
```

----------------Level 19---------------------


```
<Node exists="Yes">
    <Name>Level19</Name>
    <Ref>7</Ref>
    <Length>30</Length>
    <Width>25</Width>
</Node>
<Node exists="Yes">
    <Name>S19R</Name>
    <Ref>8</Ref>
    <Length>7.3</Length>
    <Width>1.06</Width>
</Node>
<Node exists="Yes">
    <Name>S19L</Name>
    <Ref>9</Ref>
    <Length>7.3</Length>
    <Width>1.06</Width>
</Node>
<Connection exists="Yes">
    <Name>TheLink19R</Name>
    <NodeRef>7</NodeRef>
    <NodeRef>8</NodeRef>
    <Length>1</Length>
    <ConnectionType type="Door">
    <Width>0.8</Width>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>TheLink19L</Name>
    <NodeRef>7</NodeRef>
    <NodeRef>9</NodeRef>
    <Length>1</Length>
    <ConnectionType type="Door">
    <Width>0.8</Width>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>S2019R</Name>
    <NodeRef>5</NodeRef>
    <NodeRef>8</NodeRef>
    <Length>7.3</Length>
    <ConnectionType type="Stairs">
    <Tread>0.255</Tread>
    <Riser>0.185</Riser>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>S2120L</Name>
    <NodeRef>6</NodeRef>
    <NodeRef>9</NodeRef>
    <Length>7.3</Length>
    <ConnectionType type="Stairs">
    <Tread>0.255</Tread>
    <Riser>0.185</Riser>
    </ConnectionType>
</Connection>
```


----------------Level 18---------------------


```
<Node exists="Yes">
    <Name>Level18</Name>
    <Ref>10</Ref>
    <Length>30</Length>
    <Width>25</Width>
</Node>
<Node exists="Yes">
    <Name>S18R</Name>
    <Ref>11</Ref>
    <Length>7.3</Length>
    <Width>1.06</Width>
</Node>
<Node exists="Yes">
    <Name>S18L</Name>
    <Ref>12</Ref>
    <Length>7.3</Length>
    <Width>1.06</Width>
</Node>
<Connection exists="Yes">
    <Name>TheLink18R</Name>
    <NodeRef>10</NodeRef>
    <NodeRef>11</NodeRef>
    <Length>1</Length>
    <ConnectionType type="Door">
    <Width>0.8</Width>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>TheLink18L</Name>
    <NodeRef>10</NodeRef>
    <NodeRef>12</NodeRef>
    <Length>1</Length>
    <ConnectionType type="Door">
    <Width>0.8</Width>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>S1918R</Name>
    <NodeRef>8</NodeRef>
    <NodeRef>11</NodeRef>
    <Length>7.3</Length>
    <ConnectionType type="Stairs">
    <Tread>0.255</Tread>
    <Riser>0.185</Riser>
    </ConnectionType>
</Connection>
<Connection exists="Yes">
    <Name>S1918L</Name>
    <NodeRef>9</NodeRef>
    <NodeRef>12</NodeRef>
    <Length>7.3</Length>
    <ConnectionType type="Stairs">
    <Tread>0.255</Tread>
    <Riser>0.185</Riser>
    </ConnectionType>
```

```
    </Connection>

----------------Level 17---------------------

    <Node exists="Yes">
        <Name>Level17</Name>
        <Ref>13</Ref>
        <Length>30</Length>
        <Width>25</Width>
    </Node>
    <Node exists="Yes">
        <Name>S17R</Name>
        <Ref>14</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S17L</Name>
        <Ref>15</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink17R</Name>
        <NodeRef>13</NodeRef>
        <NodeRef>14</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink17L</Name>
        <NodeRef>13</NodeRef>
        <NodeRef>15</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1817R</Name>
        <NodeRef>11</NodeRef>
        <NodeRef>14</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1817L</Name>
        <NodeRef>12</NodeRef>
        <NodeRef>15</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>

----------------Level 16---------------------

    <Node exists="Yes">
        <Name>Level16</Name>
        <Ref>16</Ref>
        <Length>30</Length>
        <Width>25</Width>
    </Node>
    <Node exists="Yes">
        <Name>S16R</Name>
        <Ref>17</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S16L</Name>
        <Ref>18</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink16R</Name>
        <NodeRef>16</NodeRef>
        <NodeRef>17</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink16L</Name>
        <NodeRef>16</NodeRef>
        <NodeRef>18</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1716R</Name>
        <NodeRef>14</NodeRef>
        <NodeRef>17</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S1716L</Name>
        <NodeRef>15</NodeRef>
        <NodeRef>18</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
```

```
            <Riser>0.185</Riser>
            </ConnectionType>
        </Connection>

----------------Level 15---------------------

        <Node exists="Yes">
            <Name>Level15</Name>
            <Ref>19</Ref>
            <Length>30</Length>
            <Width>25</Width>
        </Node>
        <Node exists="Yes">
            <Name>S15R</Name>
            <Ref>20</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Node exists="Yes">
            <Name>S15L</Name>
            <Ref>21</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Connection exists="Yes">
            <Name>TheLink15R</Name>
            <NodeRef>19</NodeRef>
            <NodeRef>20</NodeRef>
            <Length>1</Length>
            <ConnectionType type="Door">
            <Width>0.8</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>TheLink15L</Name>
            <NodeRef>19</NodeRef>
            <NodeRef>21</NodeRef>
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            <Width>0.8</Width>
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        <Connection exists="Yes">
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            <NodeRef>17</NodeRef>
            <NodeRef>20</NodeRef>
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            <ConnectionType type="Stairs">
            <Tread>0.255</Tread>
            <Riser>0.185</Riser>
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        <Connection exists="Yes">
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            <NodeRef>18</NodeRef>
            <NodeRef>21</NodeRef>
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            <Riser>0.185</Riser>
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----------------Level 14---------------------

        <Node exists="Yes">
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            <Ref>22</Ref>
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            <Name>S14R</Name>
            <Ref>23</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Node exists="Yes">
            <Name>S14L</Name>
            <Ref>24</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Connection exists="Yes">
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            <NodeRef>22</NodeRef>
            <NodeRef>23</NodeRef>
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        <Connection exists="Yes">
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            <NodeRef>22</NodeRef>
            <NodeRef>24</NodeRef>
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            <NodeRef>20</NodeRef>
            <NodeRef>23</NodeRef>
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            <Riser>0.185</Riser>
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        <Connection exists="Yes">
            <Name>S1413L</Name>
            <NodeRef>21</NodeRef>
            <NodeRef>24</NodeRef>
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			<ConnectionType type="Stairs">
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----------------Level 13---------------------

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			<Ref>25</Ref>
			<Length>30</Length>
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		</Node>
		<Node exists="Yes">
			<Name>S13R</Name>
			<Ref>26</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Node exists="Yes">
			<Name>S13L</Name>
			<Ref>27</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Connection exists="Yes">
			<Name>TheLink13R</Name>
			<NodeRef>25</NodeRef>
			<NodeRef>26</NodeRef>
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			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
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			<NodeRef>25</NodeRef>
			<NodeRef>27</NodeRef>
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			<ConnectionType type="Door">
			<Width>0.8</Width>
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		</Connection>
		<Connection exists="Yes">
			<Name>S1312R</Name>
			<NodeRef>23</NodeRef>
			<NodeRef>26</NodeRef>
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			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S1312L</Name>
			<NodeRef>24</NodeRef>
			<NodeRef>27</NodeRef>
			<Length>7.3</Length>
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			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>

----------------Level 12---------------------

		<Node exists="Yes">
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			<Ref>28</Ref>
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		<Node exists="Yes">
			<Name>S12R</Name>
			<Ref>29</Ref>
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			<Width>1.06</Width>
		</Node>
		<Node exists="Yes">
			<Name>S12L</Name>
			<Ref>30</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Connection exists="Yes">
			<Name>TheLink12R</Name>
			<NodeRef>28</NodeRef>
			<NodeRef>29</NodeRef>
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			<ConnectionType type="Door">
			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
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			<NodeRef>30</NodeRef>
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			<ConnectionType type="Door">
			<Width>0.8</Width>
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		</Connection>
		<Connection exists="Yes">
			<Name>S1211R</Name>
			<NodeRef>26</NodeRef>
			<NodeRef>29</NodeRef>
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			<ConnectionType type="Stairs">
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			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S1211L</Name>
			<NodeRef>27</NodeRef>
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----------------Level 11---------------------

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        <Ref>31</Ref>
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    <Node exists="Yes">
        <Name>S11R</Name>
        <Ref>32</Ref>
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        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S11L</Name>
        <Ref>33</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink11R</Name>
        <NodeRef>31</NodeRef>
        <NodeRef>32</NodeRef>
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    <Connection exists="Yes">
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        <NodeRef>33</NodeRef>
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    <Connection exists="Yes">
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        <NodeRef>29</NodeRef>
        <NodeRef>32</NodeRef>
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        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>
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        <Name>S1110L</Name>
        <NodeRef>30</NodeRef>
        <NodeRef>33</NodeRef>
        <Length>7.3</Length>
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        </ConnectionType>
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----------------Level 10---------------------

    <Node exists="Yes">
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    <Node exists="Yes">
        <Name>S10R</Name>
        <Ref>35</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S10L</Name>
        <Ref>36</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink10R</Name>
        <NodeRef>34</NodeRef>
        <NodeRef>35</NodeRef>
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        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink10R</Name>
        <NodeRef>34</NodeRef>
        <NodeRef>36</NodeRef>
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        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S109R</Name>
        <NodeRef>32</NodeRef>
        <NodeRef>35</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
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            <NodeRef>36</NodeRef>
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            <Tread>0.255</Tread>
            <Riser>0.185</Riser>
            </ConnectionType>
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----------------Level 9---------------------

        <Node exists="Yes">
            <Name>Level9</Name>
            <Ref>37</Ref>
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        <Node exists="Yes">
            <Name>S9R</Name>
            <Ref>38</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Node exists="Yes">
            <Name>S9L</Name>
            <Ref>39</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Connection exists="Yes">
            <Name>TheLink9R</Name>
            <NodeRef>37</NodeRef>
            <NodeRef>38</NodeRef>
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            <Width>0.8</Width>
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        <Connection exists="Yes">
            <Name>TheLink9L</Name>
            <NodeRef>37</NodeRef>
            <NodeRef>39</NodeRef>
            <Length>1</Length>
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        <Connection exists="Yes">
            <Name>S98R</Name>
            <NodeRef>35</NodeRef>
            <NodeRef>38</NodeRef>
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            <Tread>0.255</Tread>
            <Riser>0.185</Riser>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S98L</Name>
            <NodeRef>36</NodeRef>
            <NodeRef>39</NodeRef>
            <Length>7.3</Length>
            <ConnectionType type="Stairs">
            <Tread>0.255</Tread>
            <Riser>0.185</Riser>
            </ConnectionType>
        </Connection>

----------------Level 8---------------------

        <Node exists="Yes">
            <Name>Level8</Name>
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        <Node exists="Yes">
            <Name>S8R</Name>
            <Ref>41</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Node exists="Yes">
            <Name>S8L</Name>
            <Ref>42</Ref>
            <Length>7.3</Length>
            <Width>1.06</Width>
        </Node>
        <Connection exists="Yes">
            <Name>TheLink8R</Name>
            <NodeRef>40</NodeRef>
            <NodeRef>41</NodeRef>
            <Length>1</Length>
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            <Width>0.8</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>TheLink8L</Name>
            <NodeRef>40</NodeRef>
            <NodeRef>42</NodeRef>
            <Length>1</Length>
            <ConnectionType type="Door">
            <Width>0.8</Width>
            </ConnectionType>
        </Connection>
        <Connection exists="Yes">
            <Name>S87R</Name>
            <NodeRef>38</NodeRef>
            <NodeRef>41</NodeRef>
            <Length>7.3</Length>
            <ConnectionType type="Stairs">
            <Tread>0.255</Tread>
            <Riser>0.185</Riser>
            </ConnectionType>
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    </Connection>
    <Connection exists="Yes">
        <Name>S87L</Name>
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        <NodeRef>42</NodeRef>
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        <ConnectionType type="Stairs">
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        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>

----------------Level 7---------------------

    <Node exists="Yes">
        <Name>Level7</Name>
        <Ref>43</Ref>
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        <Width>25</Width>
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    <Node exists="Yes">
        <Name>S7R</Name>
        <Ref>44</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S7L</Name>
        <Ref>45</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
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    <Connection exists="Yes">
        <Name>TheLink7R</Name>
        <NodeRef>43</NodeRef>
        <NodeRef>44</NodeRef>
        <Length>1</Length>
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        <Width>0.8</Width>
        </ConnectionType>
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    <Connection exists="Yes">
        <Name>TheLink7L</Name>
        <NodeRef>43</NodeRef>
        <NodeRef>45</NodeRef>
        <Length>1</Length>
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        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S76R</Name>
        <NodeRef>41</NodeRef>
        <NodeRef>44</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
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    <Connection exists="Yes">
        <Name>S76L</Name>
        <NodeRef>42</NodeRef>
        <NodeRef>45</NodeRef>
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        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
        <Riser>0.185</Riser>
        </ConnectionType>
    </Connection>

----------------Level 6---------------------

    <Node exists="Yes">
        <Name>Level6</Name>
        <Ref>46</Ref>
        <Length>30</Length>
        <Width>25</Width>
    </Node>
    <Node exists="Yes">
        <Name>S6R</Name>
        <Ref>47</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Node exists="Yes">
        <Name>S6L</Name>
        <Ref>48</Ref>
        <Length>7.3</Length>
        <Width>1.06</Width>
    </Node>
    <Connection exists="Yes">
        <Name>TheLink6R</Name>
        <NodeRef>46</NodeRef>
        <NodeRef>47</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>TheLink6L</Name>
        <NodeRef>46</NodeRef>
        <NodeRef>48</NodeRef>
        <Length>1</Length>
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        <Width>0.8</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>S65R</Name>
        <NodeRef>44</NodeRef>
        <NodeRef>47</NodeRef>
        <Length>7.3</Length>
        <ConnectionType type="Stairs">
        <Tread>0.255</Tread>
```

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			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S65L</Name>
			<NodeRef>45</NodeRef>
			<NodeRef>48</NodeRef>
			<Length>7.3</Length>
			<ConnectionType type="Stairs">
			<Tread>0.255</Tread>
			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>

----------------Level 5---------------------

		<Node exists="Yes">
			<Name>Level5</Name>
			<Ref>49</Ref>
			<Length>30</Length>
			<Width>25</Width>
		</Node>
		<Node exists="Yes">
			<Name>S5R</Name>
			<Ref>50</Ref>
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			<Width>1.06</Width>
		</Node>
		<Node exists="Yes">
			<Name>S5L</Name>
			<Ref>51</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Connection exists="Yes">
			<Name>TheLink5R</Name>
			<NodeRef>49</NodeRef>
			<NodeRef>50</NodeRef>
			<Length>1</Length>
			<ConnectionType type="Door">
			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>TheLink5L</Name>
			<NodeRef>49</NodeRef>
			<NodeRef>51</NodeRef>
			<Length>1</Length>
			<ConnectionType type="Door">
			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S54R</Name>
			<NodeRef>47</NodeRef>
			<NodeRef>50</NodeRef>
			<Length>7.3</Length>
			<ConnectionType type="Stairs">
			<Tread>0.255</Tread>
			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S54L</Name>
			<NodeRef>48</NodeRef>
			<NodeRef>51</NodeRef>
			<Length>7.3</Length>
			<ConnectionType type="Stairs">
			<Tread>0.255</Tread>
			<Riser>0.185</Riser>
			</ConnectionType>
		</Connection>

----------------Level 4---------------------

		<Node exists="Yes">
			<Name>Level4</Name>
			<Ref>52</Ref>
			<Length>30</Length>
			<Width>25</Width>
		</Node>
		<Node exists="Yes">
			<Name>S4R</Name>
			<Ref>53</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Node exists="Yes">
			<Name>S4L</Name>
			<Ref>54</Ref>
			<Length>7.3</Length>
			<Width>1.06</Width>
		</Node>
		<Connection exists="Yes">
			<Name>TheLink4R</Name>
			<NodeRef>52</NodeRef>
			<NodeRef>53</NodeRef>
			<Length>1</Length>
			<ConnectionType type="Door">
			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>TheLink4L</Name>
			<NodeRef>52</NodeRef>
			<NodeRef>54</NodeRef>
			<Length>1</Length>
			<ConnectionType type="Door">
			<Width>0.8</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>S43R</Name>
			<NodeRef>50</NodeRef>
			<NodeRef>53</NodeRef>
			<Length>7.3</Length>
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		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S43L</Name>
		<NodeRef>51</NodeRef>
		<NodeRef>54</NodeRef>
		<Length>7.3</Length>
		<ConnectionType type="Stairs">
		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>

----------------Level 3---------------------

	<Node exists="Yes">
		<Name>Level3</Name>
		<Ref>55</Ref>
		<Length>30</Length>
		<Width>25</Width>
	</Node>
	<Node exists="Yes">
		<Name>S3R</Name>
		<Ref>56</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Node exists="Yes">
		<Name>S3L</Name>
		<Ref>57</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink3R</Name>
		<NodeRef>55</NodeRef>
		<NodeRef>56</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink3L</Name>
		<NodeRef>55</NodeRef>
		<NodeRef>57</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S32R</Name>
		<NodeRef>53</NodeRef>
		<NodeRef>56</NodeRef>
		<Length>7.3</Length>
		<ConnectionType type="Stairs">
		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S32L</Name>
		<NodeRef>54</NodeRef>
		<NodeRef>57</NodeRef>
		<Length>7.3</Length>
		<ConnectionType type="Stairs">
		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>

----------------Level 2---------------------

	<Node exists="Yes">
		<Name>Level2</Name>
		<Ref>58</Ref>
		<Length>30</Length>
		<Width>25</Width>
	</Node>
	<Node exists="Yes">
		<Name>S2R</Name>
		<Ref>59</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Node exists="Yes">
		<Name>S2L</Name>
		<Ref>60</Ref>
		<Length>7.3</Length>
		<Width>1.06</Width>
	</Node>
	<Connection exists="Yes">
		<Name>TheLink2R</Name>
		<NodeRef>58</NodeRef>
		<NodeRef>59</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink2L</Name>
		<NodeRef>58</NodeRef>
		<NodeRef>60</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S21R</Name>
		<NodeRef>56</NodeRef>
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		<NodeRef>59</NodeRef>
		<Length>7.3</Length>
		<ConnectionType type="Stairs">
		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>S21L</Name>
		<NodeRef>57</NodeRef>
		<NodeRef>60</NodeRef>
		<Length>7.3</Length>
		<ConnectionType type="Stairs">
		<Tread>0.255</Tread>
		<Riser>0.185</Riser>
		</ConnectionType>
	</Connection>

----------------Level 1---------------------

	<!-- The exit Node -->
	<Node exists="Yes">
		<Name>Exit</Name>
		<Ref>61</Ref>
		<NodeType>Safe</NodeType>
		<!-- dimensions are not required for a safe Node -->
	</Node>
	<Connection exists="Yes">
		<Name>TheLink1R</Name>
		<NodeRef>59</NodeRef>
		<NodeRef>61</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>TheLink1L</Name>
		<NodeRef>60</NodeRef>
		<NodeRef>61</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
		<Width>0.8</Width>
		</ConnectionType>
	</Connection>
</EvacuatioNZ_Map>
```


- **POPULATE file**


```
<EvacuatioNZ_Populate version="1.2">

--------Level 21------------

	<Definition>
		<People>58</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>92</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>8</Probability>
		</PersonType>
	</Definition>

--------Level 20------------

	<Definition>
		<People>58</People>
		<Log>no</Log>
		<Node type="single">4</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>92</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>8</Probability>
		</PersonType>
	</Definition>

--------Level 19------------

	<Definition>
		<People>58</People>
		<Log>no</Log>
		<Node type="single">7</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>92</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>8</Probability>
		</PersonType>
	</Definition>

--------Level 18------------

	<Definition>
		<People>70</People>
		<Log>no</Log>
		<Node type="single">10</Node>
		<PersonType>
```

```
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 17------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">13</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 16------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">16</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 15------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">19</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 14------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">22</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 13------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">25</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 12------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">28</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 11------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">31</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
```

```
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 10------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">34</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 9------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">37</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 8------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">40</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 7------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">43</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 6------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">46</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 5------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">49</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>

--------Level 4------------

        <Definition>
            <People>58</People>
            <Log>no</Log>
            <Node type="single">52</Node>
            <PersonType>
                <Name>AbleBodied</Name>
                <Probability>92</Probability>
            </PersonType>
            <PersonType>
                <Name>Disable</Name>
                <Probability>8</Probability>
            </PersonType>
        </Definition>
```

--------Level 3------------


```xml
<Definition>
	<People>58</People>
	<Log>no</Log>
	<Node type="single">55</Node>
	<PersonType>
		<Name>AbleBodied</Name>
		<Probability>92</Probability>
	</PersonType>
	<PersonType>
		<Name>Disable</Name>
		<Probability>8</Probability>
	</PersonType>
</Definition>
```


--------Level 2------------


```xml
	<Definition>
		<People>58</People>
		<Log>no</Log>
		<Node type="single">58</Node>
		<PersonType>
			<Name>AbleBodied</Name>
			<Probability>92</Probability>
		</PersonType>
		<PersonType>
			<Name>Disable</Name>
			<Probability>8</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```


- **SIMULATION file**


```xml
<EvacuatioNZ_Simulation version="1.2">
	<TimeMax>4000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.5</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="1.5">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


- **SCENARIO file**


```xml
<EvacuatioNZ_Scenario version="1.2">
	<Simulations>100</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<DumpPreEvacuationTimes>Yes</DumpPreEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


- **PERSON TYPE file**

<u>Normal Maximum Speed Distributions</u>


```xml
EvacuatioNZ_PersonType version="1.2">
<PersonType name="AbleBodied">
	<ExitBehaviour>Default</ExitBehaviour>
	<Speed type="distribution">
		<Distribution type="normal">
			<Mean>1.35</Mean>
			<StandardDeviation>0.3</StandardDeviation>
		</Distribution>
```

```
			</Speed>
			<PreEvacuation type="distribution">
				<Distribution type="weibull">
					<Alpha>233</Alpha>
					<Beta>3</Beta>
				</Distribution>
			</PreEvacuation>
		</PersonType>
		<PersonType name="Disable">
			<Speed type="distribution">
				<Distribution type="normal">
					<Mean>1.0</Mean>
					<StandardDeviation>0.3</StandardDeviation>
				</Distribution>
			</Speed>
			<ExitBehaviour>Default</ExitBehaviour>
			<PreEvacuation type="distribution">
				<Distribution type="weibull">
					<Alpha>233</Alpha>
					<Beta>3</Beta>
				</Distribution>
			</PreEvacuation>
		</PersonType>
		</EvacuatioNZ_PersonType>
```

Constant Maximum Travel Speeds

```
		<EvacuatioNZ_PersonType version="1.2">
		<PersonType name="AbleBodied">
			<ExitBehaviour>Default</ExitBehaviour>
				<Speed>1.35</Speed>
			<PreEvacuation type="distribution">
				Distribution type="weibull">
					<Alpha>233</Alpha>
					<Beta>3</Beta>
				</Distribution>
			</PreEvacuation>
		</PersonType>
		<PersonType name="Disable">
				<Speed>1.0</Speed>
			<ExitBehaviour>Default</ExitBehaviour>
			<PreEvacuation type="distribution">
				<Distribution type="weibull">
					<Alpha>233</Alpha>
					<Beta>3</Beta>
				</Distribution>
			</PreEvacuation>
		</PersonType>
	</EvacuatioNZ_PersonType>
```

- **PERSON TYPE file**


```
<EvacuatioNZ_ExitBehaviour version="1.2">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="MinDistanceToSafe">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```