Comparison of Evacuation Times Using Simulex and EvacuatioNZ Based on Trial Evacuations

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Abstract

The purpose of this research is to assist in the development of EvacuatioNZ. EvacuatioNZ is a course network, risk assessment evacuation model that is currently under development at the University of Canterbury. Previous research has been done on the flow mechanics of the model and has shown satisfactory results. This research validates several components of human behaviour in the model and compares the model with the actual trial evacuations. The new features of human behavioural aspects are the pre-movement time and the choice of exit. A second commercially available evacuation model, Simulex, is used as a comparison.

Two evacuation simulations are considered in this report: the trial evacuations at an industrial site carried out in 2002 and at a lecture theatre studied by Kimura and Sime (1989). Results from the two evacuation simulations show that Simulex has a faster flow rate and a quicker evacuation time, and EvacuatioNZ results gave a more accurate representation of the actual events. The two evacuations also show that the pre-movement time is an important factor to the overall evacuation time.

EvacuatioNZ is currently unable to model a lecture theatre or setting similar to it accurately as a single node. Further research should be done on the model so that it can take into account the complexity of the room setting. The current version of EvacuatioNZ (Version 1.01) can be used for design purposes under certain circumstances. However, users must know the limitations of the evacuation model and proceed with care.

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1. Introduction

An evacuation model that is currently under development at the University of Canterbury is called EvacuatioNZ. The model incorporates the Monte Carlo approach to produce probability distributions of evacuation times. Recent research has been done on the flow mechanics of the model (Teo, 2001). However, the model still requires more validation as more of the components need to be examined so that it can be used with reasonable confidence by designers and fire engineers.

The purposes of this research are to validate the components of human behaviour in the model and compare the model with actual incidents. The actual incidents under consideration in this report are trial evacuation data. The new features that will be discussed in this report are the pre-movement time and the choice of exit. Moreover, a simulation result from the model will be compared with another evacuation model called Simulex. This will help to verify if the behavioural effects influence the evacuation process. It can also address any limitations in the model and suggest where it needs additional development.

Two trial evacuations, which represent fire drills, will be discussed in this report. One was conducted at an industrial site and the other was extracted from the literature, which was a lecture theatre evacuation. Both of these evacuations are good representation of a fire situation as the drills were unannounced. They represent closely to the situation that the occupants would face if the fire were located in a remote area, or on an upper floor of the building, and the only indication of fire would be the sudden sound of the fire alarm signal.

1.1 Background

Nowadays, designers and fire engineers use evacuation models to assess the safety of the buildings and their ability to provide sufficient time for the occupants to evacuate safely in the event of a fire or other emergency. There are several types of evacuation models currently available. Some models do not incorporate human behaviour during the evacuation, and these are often referred to as 'ball-bearing' models; others do incorporate human behaviour and are more realistic. EvacuatioNZ belongs to the latter models.

EvacuatioNZ is a probabilistic, coarse network evacuation model currently under development at the University of Canterbury. The program is written in the C++ language using Microsoft Visual C++. It allows easy modification and the addition of new components, without the need to reproduce the entire model. The basic components of the movement in the previous version of the model (Version 1.0e) have been examined and should not be used for design purposes, as it needs to incorporate the latest findings from research into human behaviour in fire and emergency evacuation incidents.

In addition, a second model that will be used in this research is Simulex. Simulex is an evacuation program capable of simulating the evacuation of large populations through geometrically complex buildings. It is a more sophisticated ball-bearing model that uses the fine network approach and does not incorporate many aspects of human behaviour.

1.2 Objectives

The objectives of this study are:

- To study the human behaviour in fires and how much it influences the evacuation process in order to validate the components of human behaviour in the model.

- To assist in the development of the EvacuatioNZ model to give satisfactory results that are representative of actual events.

- To compare simulation results from two different models with data from two actual events, which are trial evacuations.

1.3 Outline of this report

This report will compare the actual and predicted evacuation times. It will also provide information and validation of new features and behavioural aspects that are incorporated in EvacuatioNZ. The current version that is under discussion in this report is Version 1.01. However, it is noted that this study will be limited by the features and the ability in this current version. The flow mechanics of the model will not be discussed in detail and further information can be found in Teo (2001).

Chapter 2 will summarise the latest findings from research into human behaviour in fire or emergency evacuation events, such as exit choice and pre-movement time. It will also provide a general idea of evacuation models and brief introductions on a number of examples on the available evacuation models.

Chapter 3 will describe the two models used in this research, Simulex and EvacuatioNZ. It will also present a few newly incorporated features in EvacuatioNZ. It will subsequently compare the two models in terms of their principles and assumptions. Chapter 4 will describe the component testing that was carried out on the model in order to simulate the two trial evacuations, and then it will discuss the problems encountered during the validation process.

Chapter 5 will describe the methodology and the results of the trial evacuation at the industrial premises. Simulex and EvacuatioNZ will be used to model this evacuation in Chapter 6. Similarly, in Chapter 7, a lecture theatre evacuation will be modelled and analysis and discussion will be made regarding this trial evacuation.

Chapter 8 will discuss the general findings obtained from both the simulation results, limitations of EvacuatioNZ and discuss further research ideas. Finally, conclusions will be last presented in Chapter 9.

2. Literature Review

2.1 Human behaviour in Fires

Studies of human behaviour and movement in fires have been carried out for at least thirty years. Designers and fire engineers continue to implement new concepts in building fire safety design, using earlier evacuation models, which are conventional ball-bearing models, to models that incorporate human behaviour aspects and produce results that are more realistic. Studies have shown that the behavioural influences have delays throughout the whole evacuation process, which occur before and during the movement phase.

Typical evacuation process is shown in Figure 2.1. This is similar to the evacuation time given by the following equation (Buchanan, 2001):

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

where t_d is the time from ignition until detection of the fire; t_a is the time from detection until an 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, collect belongings, fight the fire; t_t is the travel time or the movement time, being the actual time required to escape route until a places of safety is reached, including way-finding; and t_q is the queuing time at doorways or other obstructions.

From the above equation, the middle two terms, t_o and t_i, refer to pre-movement time while the last two terms, t_t and t_q, represent to movement time. This shows that human behaviour aspects play an important role in the whole evacuation process. Specific behaviours may occur during the evacuation, or more precisely during the movement phase may include panic, re-entry, group affiliation and movement through smoke.

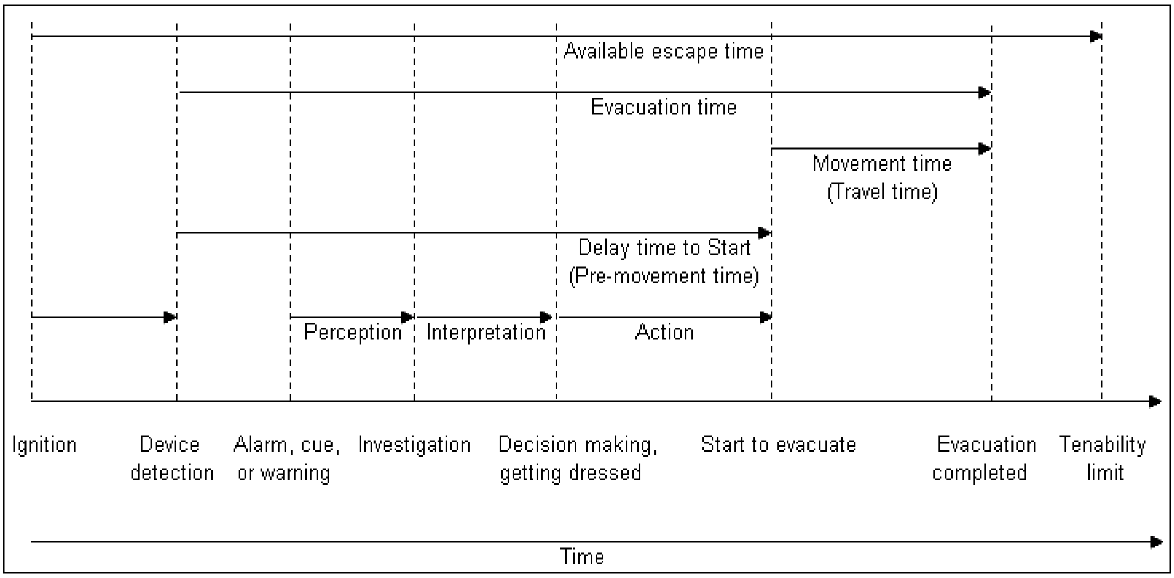


Figure 2.1: Sequence of occupant response to fire. (Modified from Proulx, 2002)

Panic is the behaviour observed during evacuations that people have usually mislabelled. It is a type of non-adaptive behavioural response. The non-adaptive behaviour referred to the behaviour that might impede the evacuation of others or worsen the fire situation. However, some behaviour or actions taken that might result in negative consequences, which appear to be non-adaptive, would later found out to be the failed attempts in adaptive behaviour.

Sime (1990) in his study compiled other studies on the concept of panic, which is characterised as: "Panic in a fire is a concept attributed in a retrospective, contemporary or anticipatory fashion by and to different role groups with differing degrees and kinds of involvement in a fire. It is used as an explanation of a state of anxiety, pattern of behaviour in a fire on the part of an individual, group or crowd."

This form of behaviour should not be entirely ignored as it can affect the evacuation procedure; however, panic behaviour rarely occurs and is not a major formative factor that influences the efficiency of the evacuation. Panic behaviour has been observed in fire incident such as Beverly Hills Supper Club fire (cited in Bryan, 2002).

Another behaviour observed during the evacuation is re-entry. This behaviour has often been considered a non-adaptive behaviour as it affects the effectiveness and efficiency of the evacuation of others. However, the re-entry behaviour is usually carried out in a rational, purposeful way and aware of the danger, which is more of an adaptive behaviour. This behaviour has been observed in the Arundel Park fire incident which indicated about one third of the individuals interviewed had re-entered the building (cited in Bryan, 2002). The main reason may have been the primary group, such as a father or a husband, in search of the other family members. In addition, a statistical study has been done on the re-entry behaviour in residential occupancies in United States showed approximately 27.9 percent of the people re-entered the premises.

Group affiliation behaviour has also been observed especially in a crowd movement. Family members or groups of friends tend to stick together. As a result, it may affect the movement of the others.

It is found in many fire incidents that occupants can move through smoke. Wood (1990) in his study has found that 60 percent of the population was seen to move through smoke. Movement through smoke would add at least 20m extra distance to their escape route under limited visibility condition (cited in Bryan, 2002). As a result, occupants sometimes are forced to turn back. This is verified in the study of human behaviour in the World Trade Center evacuation in1993, Fahy and Proulx (1997) found that 94 percent of the occupants in Tower 1 and 70 percent in Tower 2 attempted to move through smoke, but 75 percent of these individuals turned back.

All the above behaviours will certainly influence the total evacuation time. However, pre-movement time is also an important contribution to the total evacuation time, which is discussed in the following section.

2.2 Pre-movement time

Pre-movement time is referred as “delay time to start” in Figure 2.1. It has a major influence in the total evacuation time. It consists of the time occupants take to perceive any cues, alarm or warning, the time occupants take to interpret the situation by searching for more information before making a decision to evacuate, and the time occupants use to engage in other actions before starting to evacuate, such as getting dressed.

Individuals have different level of perceptions to alarm or cues. This may, however, be influenced by the response behaviour of others in the same situation, especially when the fire incident cues are relatively ambiguous. Generally, occupants are hesitant to overreact, especially in the presence of other occupants. Latane and Darley (1970) in their studies found that the occupants appeared to defer making emergency decision when they are in groups. As a result, occupants may be prompt to non-adaptive flight behaviour due to the short available evacuation time. This is also found in MacLennan’s study (cited in Nelson and Mowrer, 2002) that group interaction played an important part in decision-making and resulted in a delay response.

The awareness of cues is often the major contribution to the pre-movement time. This comes down to the reliability of fire alarms and the evident of the physical cues. In the absence of alarm signals, occupants would have to rely on the presence of physical cues such as smoke, flame or noises. Potential egress times would be spent on investigating or seeking more information before making a decision. Studies have shown that a verbal or vocal alerting system is most effective in reducing pre-movement time (cited in Bryan, 2002). However, occupant may question the credibility of the verbal directive messages if they are inconsistent with other fire cues.

Benthorn and Frantzich (1996) studied the perception and the understanding of the occupants to the meaning of the alarm signal and the spoken message. It is shown that a ring signal is not well perceived as a general specified warning signal by most of the occupants, while a spoken message has greater impact on the occupants’ perception and the occupants would react accordingly to evacuate the building. However, the spoken message in their study did not give any indication for the occupants about which exit should be chosen.

Proulx and Sime (1991) also supported the use of directive public announcement. They have studied the effect of different emergency information strategies on the occupants' perception in an underground rail station. Their study concluded that public announcements and the presence of staff supervision have reduced the pre-movement times significantly compared with the alarm bells.

Proulx and Fahy (1997) have reviewed case studies on pre-movement time. In the residential building drills, there were four mid-rises (6-7 storeys high, an average of 150 occupants) and two high-rises (12-15 storeys high, an average of 300 occupants). Two of the mid-rises that were rated with "good alarm" had a combined average time to start of 169 seconds; while the other two, with a "poor alarm", had a combined average time to start of 515 seconds. "Good alarm" was given when the occupant rated it as "loud enough or too loud"; whereas "poor alarm" was given when the occupant rated it as "not too loud". It was found that elderly people and people with disabilities tended to stay in their apartments and wait to be rescued, while others did not hear the fire alarm, and only became aware of the situation when firefighters knocked on the door. There was also a problem when the alarm was so loud that the firefighters had difficulties communicating with the remaining occupants. As for the two high-rises, both of them were rated with "good alarm" and the times to start were significantly different, 168 seconds and 319 seconds. The longer delay was due to the snowfall outside and thus the need to get dressed. It was noted that the occupants of all buildings were informed an evacuation would take place in the coming week without knowing the exact date.

In the study of office building drills, the two mid-rises were rated with "good alarm" and each had the average time to start of 36 seconds and 63 seconds respectively. The time to start in the office drills were much shorter compared to the residential drills. This was due to the lack of occupant training and the presence of fire wardens in the residential building. Moreover, the office buildings carried out a trial evacuation annually.

Also included in Proulx and Fahy's (1997) study, pre-movement times for the two fire incidents were reviewed. The two fire incidents were Forest Laneway Fire and the World Trade Center bombing in 1993. The average time to start for the former fire was 198 minutes. The reason was that many occupants stayed in their apartments to wait for rescue. The average times to start for Tower 1 and Tower 2 of the World Trade Center were 11 minutes and 2 seconds, and 25 minutes 24 seconds respectively. Tower 2 had longer time to start because there was less cues in the building compared to Tower 1 where the bombing was closer.

Brennan (1997) has examined the occupants response times in office and residential building fires. It was found that the time from the first alert to the start of the evacuation varied from 1 to 6 minutes in an office building fire incident and from 1 minute to over 20 minutes in the case of residential apartment building.

Frantzich (2001) studied the occupants behaviour and response time from unannounced evacuations in three different furniture warehouses, two 1- story and one 3-storey building. These were performed when occupant density was not very high. These experiments were initiated by a pre-recorded voice messages in each warehouse. It was found that the response times were typically less one minute. Most of the customers responded within a 30 second period while the others standing at the cash desk were more reluctant to leave and had longer pre-movement time. The shorter response time was mainly due to the pre-recorded voice message and the well- trained staff. It was observed that many the customers tended to use known exits even though they were standing next to an emergency exit, which resulted in many emergency exits not being used.

For designers and fire engineers to be able to incorporate pre-movement time in their design, one must evaluate each possible scenario about how occupants would response. In the environment where occupants are familiar with evacuation procedure or have been in evacuation before, the pre-movement time is usually shorter. It should be noted that where there is no queuing in the escape route, in the stairs or corridors, the time to evacuate is strongly dependent on the time to start, the distance to travel and the speed of movement.

It is noted that the pre-movement time discussed later in this report will have the same definition as described earlier in this section.

2.3 Exit choice

Occupants always make a decision about which route to choose when evacuating the building. Kimura and Sime (1989) in their study about exit choice indicated that people prefer to leave by the same door as they had entered, that is, exit through the familiar route.

Benthorn and Frantzich (1996) studied how people react to fire alarm and choice of exit with respect to the distance to the exit and the status of emergency exit (opened or closed). The theory proposed in their study was called the Theory of Choice by Distance and Familiarity. It says that there is a relationship between the distance of an exit and its familiarity, to the exit choice made by the occupants. It is shown that the occupants prefer a familiar exit even though the distance is longer than the nearest exit, unless the nearest exit is opened and people are able to see that it leads to the outside. Hence, an open exit attracts more people than a closed exit. Designers should be able to foresee the high-load use of the general routes by the occupants and thus reduce the “bottleneck” situation.

Furthermore, studies show that the familiarity may extent to the relationship between the staff members and the occupants. This will eventually influence the choice of exits made by the occupants.

Sime (1994) summarised the factors that influence the direction of the occupants’ escape behaviour in the Summerland leisure complex fire which were the role of public and staff, the location of the group members and exits, guidance to exits from staff, group movement and familiarity with escape route. From the research literature reviews, eleven factors in relation to the distance, timing and exit choice behaviour have been suggested, which include the familiarity of the escape route and building layout. Assumptions and principles that should lead the fire safety engineering design are stated.

One of the factors that will affect the efficiency of the evacuation is way-finding. This is often the case for occupants who are not familiar with the building environment. Typically, it can be solved by providing exit directional signs. However, the placing of the signs may not achieve their original purpose because it is covered once the smoke levels start to drop. In this case, occupants may follow the route they can see. Moreover, occupants would turn back when they reach a dead end, or redirect to another egress route. The latter behaviour is an illustration of the occupant's ability to adjust their escape route according to the assessment of the situation. This is more likely to happen when the occupant is in a long queue or is able to see fewer occupants at another exit.

Sekizawa et al (1999) examined the occupants' behaviour in the highrise apartment building fire in Hiroshima City. It is found that the occupants are likely to choose the route they usually used (44%) or a safer route (29%) rather than a closer route. It is also expected that more occupants would use elevators if they live on a higher floor.

In conclusion, there are still many uncertainties of how to account for human behaviour in fire safety system designs. One thing for sure is it does influence the overall evacuation process. Fahy (2001) provided a list of pre-movement times extracted from a number of case studies. In addition, Society of Fire Protection Engineers (SFPE) has recently reviewed a draft of an Engineering Guide to Human Behaviour in Fire (August 2002).

2.4 Existing evacuation models

Nowadays, designers and fire engineers increasingly use evacuation models to simulate whether their buildings or public places, such as train stations, are able to provide adequate time for the occupants to evacuate in an emergency. As a result of that, evacuation models are frequently being modified, and more features are implemented in the models to produce more realistic results.

Sime (1994) in his study stated that there are two different ways to model people moving around buildings, which are in terms of movement of occupants or their behaviour. The first way of modelling is called a ‘physical science’ or ‘ball-bearing’ model of human movement. It relates to the physical science and is the predominant model of escape behaviour in fire codes. The second way of modelling is called a ‘social science’ or psychological model of human reactions. People are assumed to be behaving irrationally in ‘physical science’ model whereas people in ‘social science’ model are thinking and acting accordingly.

Gwynne et al (2002) investigated the behavioural aspects required for evacuation modelling. They have categorised four major factors that influenced evacuation performance and suggested those to be represented within an evacuation model. The four broad areas are: configuration of enclosure, environmental factors inside the structure, procedures implemented within the enclosure, and, most important of all, behaviour of the occupants. The influence of an occupant’s personal attributes, such as physical, psychological and sociological, will be affected by the other three broad areas. It concludes that a model should consider the factors on which these decisions are based, rather than treating occupants as instinctive entities.

In terms of the methodologies of evacuation models (Gwynne et al, 1999), there are different approaches to the evacuation analysis and different ways of representing the enclosure, the occupants and their behaviour. The behavioural perspective is generally similar to Sime (1994).

There are three types of approaches to the evacuation analysis, these are optimisation, simulation and risk assessment. The optimisation model ignores the non-evacuation activities as it assumes the occupants to evacuate in an efficient manner. The simulation model is an endeavour to embody the behaviour and movement exhibited during evacuations to predict the decision-making and escape routes. The risk assessment model produces a probability distribution of values from the repeated runs of each simulation and thus provides statistically significant values for evacuation times.

For any risk assessment model, convergence testing must be done before analysing any simulation results. It is important to determine the number of iterations that is needed to give a closest value to the converging output mean.

There are two ways to model a building space, which are fine network approach and coarse network approach. The former represent a space as a network of identical nodes. This approach is usually an accurate representation of the building geometry and it requires CAD drawings. However, the latter approach represents a space as a node and an arc to connect to the next node. The user can enter a set of properties to each of them. An arc represents the actual connection of the building space. The user can also model the space with more than one node, such as for a long corridor. Although the latter approach requires less computational effort, it does not take into account of local interaction or overtaking of people.

The population can be represented in either a global or an individual perspective. With the global perspective, the occupants are treated as a group, where each occupant is identical and has no individual characteristics. With the individual perspective, individual occupants have been assigned to person attributes, either randomly or by the user.

The following are examples of evacuation models:

- BuildingEXODUS (Owen et al, 1997, Gwynne, 2002)
  BuildingEXODUS is a behavioural, fine network evacuation model. It comprises five core interacting submodels, the Occupant, Movement, Behaviour, Toxicity and Hazard submodels. The software, written in C++ using Object Oriented techniques, comprises a set of rules or heuristics that defines the function of each submodel. Using these rules, EXODUS tracks the trajectory of all individuals as they make their way out of the enclosure or are overcome by the fire hazards such as heat and toxic gases.

  There are six different speeds assigned to different movements, and they are: run walk, crawl, leap, travel stairs-up and travel stairs-down. These speeds represented are the maximum unimpeded speed the occupant can achieve. The behaviour submodel functions on two levels, which are Global and Local. The formal involves instigating an escape strategy, while the latter concerns the occupants' to local situation such as overtaking. In addition, it also can demonstrate behavioural aspects of group bonding, redirection and re-entry.

- EVACNET+ (Kisko and Francis, 1985)
  EVACNET+ is an optimisation, course network evacuation model and public domain program. It requires a list of arcs and nodes as input, and generates a minimum evacuation time to evacuate the building. It also identifies bottleneck arcs. For each arc, the user needs to specify the traversal time and the flow capacity. The model does not take into account fire-related inputs like smoke and flame propagation and is a ball-bearing model. However, the program produces quite a lot of results that are beneficial in the analysis of the building scenarios. It provides details about the evacuation at each time step. EVACNET+ represents a global evacuation perspective, not an individual evacuation perspective. However, it does provide useful information about the evacuation plan to the potential evacuees.

- EXIT89 (Fahy,1996)

  EXIT89 is an evacuation model for high-rise buildings. It is able to handle the evacuation of large populations. The model is capable of accommodating up to 700 occupants in a total of 308 nodes or building spaces over 100 time intervals. The inputs to the model comprise a network description of the building, dimensions of the nodes and smoke data from CFAST if the effect of smoke blockage is to be considered. The model allows the occupants to use either the shortest evacuation routes or the preferred routes, but does not include many behavioural aspects in its modelling especially in large population scenarios.

  The model is based on a local perspective. It also allows the user to fix a delay by location or random delays for specific occupants. Furthermore, the model is capable of recalculating the escape routes when a location is blocked by smoke.

  Two new features have been recently added to the model and they are the effect of control flows and the movement of occupants both up and down the stairwells. These features are essential for any models applicable to the high-rise buildings.

- EXITT (Kostreva and Lancaster, 1998)

  EXITT is a sub-program in HAZARD I designed to simulate evacuation of the occupants from a burning building. It is a coarse network model and is currently limited to 12 rooms and 35 nodes. The inputs of EXITT include a network diagram of a building, dimensions of each space and a description of the occupants. It also incorporates some behavioural aspects in the model, such as investigation of the fire. It simulates the occupants based on a global perspective. All individuals will have the same speed and same behaviour, and the movement is deterministic. It produces as output an optimal escape route.

  In addition, the model is also able to include the smoke data that allows the model to recalculate the escape routes if a location is blocked by smoke. Nevertheless, it does not have queuing effects, therefore it is limited to large buildings or high population densities premises.

- CRISP (Ghosh and Fraser-Mitchell, 1999)

  Computation of Risk Indices by Simulation Procedures (CRISP) is a risk assessment model. It calculates fire growth, spread of smoke and gases, egress and detection systems. It uses a fine network approach to model a building space. Two human behaviour aspects are incorporated in the model to calculate the egress of the occupants. CRISP assigns individuals with specific “roles” and each role would perform different tasks. Each task is associated with a response time. CRISP can be used in combination with other models to increase the accuracy of calculations. Therefore, it can simulate the behaviour of the occupants in response to the conditions they encountered.

3. Two models utilized

3.1 Simulex: Version 11.1.3 [Thompson et al. (1997)]

Simulex is an evacuation program capable of simulating the evacuation of large populations from a large complex building. It allows the user to create a plan layout that includes multiple floor plans connected by stairs in DXF format directly from the commercially available CAD programs as an input for the building. Occupants can be added either one by one or as groups at any location on the 2D floor plans.

The user will need to place the final exits and links on the floor plan. Links are the boundaries of any spaces such as staircases. Once the model finishes calculating the travel distances throughout the whole building, which is the shortest distance to the exit, and defining the population, the user can start simulations. The model allows a maximum of 100 links, 100 staircases and 50 exits in the current version of the program.

Response time can be specified to the occupants. By default it lies randomly in between 0.5 to 1.5 seconds. There are three other response time distributions available and they are normal, triangular and uniform distribution. In Simulex, an occupant is represented by three circles and they are: the larger circle in the middle represents the torso and two smaller circles represent the shoulders. The movement parameters have allowed the model to simulate a realistic crowd movement. These features are such as normal unimpeded walking speed, reduction of walking speed due to the proximity of other occupants, overtaking, sidestepping and body twisting. However, Simulex only models a number of behavioural aspects such as choice of exit and response time.

Simulex is a more sophisticated ball-bearing model that uses the fine network approach. As a result, it requires a large amount of time to compute. One of the best features in the model is a visual display of the evacuation. The user is able to view the movement of any individuals at any location during the evacuation. Therefore, the user is able to see the occupants overtaking, sidestepping and queuing during the evacuation. It helps to identify any bottleneck areas and problems encountered during the simulation such as being stuck at links.

The following is a summary of Simulex's principle assumptions from the help file in Simulex about the geometry of escape and methods of individual movement:

- Each person is assigned to a normal, unimpeded walking speed
- Walking speeds are reduced as people get closer together
- Each person heads towards an exit by taking a direction that is at right angles to the contours shown on the chosen distance map.
- Body rotation, overtaking, sideways stepping and small degrees of back-stepping are all accommodated.

3.2 EvacuatioNZ model (Teo, 2001)

EvacuatioNZ is an evacuation model that is currently under development at the University of Canterbury. It is a risk assessment model that incorporates the Monte Carlo approach in producing probability distributions of evacuation times collected from the repeated runs of each simulation. It also uses the coarse network approach that eases the representation of the building space and the occupants in an individual perspective. The later version of the program will incorporate the latest research findings in human behaviour. The current version that is under discussion in this report is Version 1.01.

The program is written in the C++ language using Microsoft Visual C++. C++ is a current industry standard language and widely used. As C++ is an object-oriented programming language, it allows easy modification and the addition of new components.

EvacuatioNZ advances on the other evacuation models, as it can simulate as many number of occupants and nodes as the user desires. Users can model as many occupants in as many nodes, and are only limited by the processing capacity of their computer. This is very useful as buildings become larger, higher and more complex.

Previous research done by Teo (2001) was to assist in the development of this model by carrying out validation processes that tested the model’s components. It was found that the basic components of movement were working satisfactorily; however, that previous version, Version 1.0e, should not be used for design purpose until more validation is done. Refer to Teo (2001) for further detailed information of the basic mechanics of the model.

3.2.1 Input files

EvacuatioNZ has two types of input files, which are the files that illustrate the physical aspects of the scenario and those that illustrate the behavioural aspects. Six elementary input files require the input of data. These files are called: MAP, POPULATE, SIMULATION, SCENARIO, PERSON TYPE and EXIT BEHAVIOUR. The first four files are related to the physical aspects and the last two files are related to the behavioural aspects. All input files are in the Extensile Mark-up Language (XML), thus the user needs some basic knowledge of this language.

It must be noted that sample files are given to show how to the construct these six input files. They are not necessarily able to be used to execute a complete evacuation simulation.

(a) MAP file
This file defines the building space. The user can also specified a name for this MAP file as shown in label 2 in the sample file below. It can be sorted into two fundamental parts, which are nodes (labelled 3, 4 and 5 in the sample file below) and connections (6 and 7). Areas of a building such as rooms, corridors or staircases are represented as nodes. Each node (label 3) is specified with a name, a reference number and its dimensions. These nodes will need to be connected through paths. Each connection or path (label 7) is also specified with a name, the reference numbers of the two nodes that defined this connection and the distance required to travel between the nodes. A connection may also include a door, which will constrict the flow, and may be level such as stairs or slope (see label 7). In addition, the user can specify a behavioural aspect in a connection such as a preferred route or an exit sign route (in label 6). This enables the user to simulate a familiar escape route or an escape route directed by exit signs during an emergency.

The dimensions of the nodes are essential, as they will determine whether the maximum number of occupants is not exceeded, which is predetermined by the maximum node density in the SIMULATION file (label 3 in the SIMULATION file). An exit is modelled as a node, regardless of its dimensions and it is always a safe node (label 5). A connection length is referred to the travel distance from one node to the next. It is recommended that maximum travel distance and “random start” feature should be used, where the former tends to be more conservative and the latter is more realistic. It is noted that travel distance specified by the user will not be used when “random start” feature is activated. “Random start” feature will be discussed later in the SCENARIO files (see label 3 in the SCENARIO file)

The MAP file is very flexible. It allows the user to disconnect any connections and/or nodes by simply using “NO” at the first line of each node or connection (see first line of label 3). Besides, the user can create as many connections from or towards a node as logically possible. Each connection refers to a two-way direction in this current version, which means from node 1 to node 2 and from node 2 to node 1. However, this ability presents a problem in some situations. This will later be discussed in Chapter 4. A sample of the MAP file is shown below:

```
<EvacuatioNZ_Map version="1.01">                          1
    <Description>Building "A" </Description>              2
    <Node exists="Yes">
        <Name>A1</Name>
        <Ref>1</Ref>                                      3
        <Length>42.5</Length>
        <Width>15</Width>
    </Node>
    <Node exists="Yes">
        <Name>A2</Name>
        <Ref>2</Ref>                                      4
        <Length>27</Length>
        <Width>30</Width>
    </Node>
    <Node exists="Yes">
        <Name>Exit3</Name>
        <Ref>3</Ref>                                      5
        <NodeType>Safe</NodeType>
    </Node>
    <Connection exists="Yes">
        <Name>Route_1</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>2</NodeRef>
        <Length>57</Length>                               6
        <ConnectionType type="Door">
            <Width>2.0</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
    </Connection>
```

```
<Connection exists="Yes">
        <Name>Route_2</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>3</NodeRef>
        <Length>56.5</Length>
        <ConnectionType type="Door">
            <Width>0.78</Width>                          7
        <ConnectionType type="Stairs">
            <Tread>0.28</Tread>
            <Riser>0.18</Riser>
        </ConnectionType>
  </Connection>
</EvacuatioNZ_Map>                                      8
```

(b) POPULATE

This file is where the user specifies the number and type of occupants in each node. The type of occupant is defined in the PERSON TYPE file (see label 1 in the PERSON TYPE file). For example, “Normal1” at line 6 in label 3 corresponds to the person type defined at line 1 in label 1 in the PERSON TYPE file. “Normal1” is just a name given by the user and can be any name the user desires. The user can also specify a different type of occupant in each node (label 1) or can specify more than one type (label 3), which the user can then set a probability for each person type. The probability will determine how likely the occupant is being selected in a population and will add up to 100 percent (see label 3).

There is also an option for the user to choose whether to log each occupant’s movements and decision-making processes (line 3 in label 1). In addition to that, the user can also create a file so that only a certain number of occupants would generate the log files. Similar to the MAP file, the POPULATE file is very flexible and can be created in the way as the user desired. There are five samples of the files below and each shows a different way of modelling the population.

Sample one shows a general way to construct a POPULATE file. Label 1 describes that all nine occupants in node 1 will have the same “Normal” person type as define in the PEROSN TYPE file. Sample two shows how to model two different person types in a node. It indicates that 50% of the occupants in Node 1 will have “Normal 1” person type and the other 50% will have “Normal 2” person type.

Sample one

```
<EvacuatioNZ_Populate version="1.01">
    <Definition>
            <People>9</People>
            <Log>no</Log>
            <Node type="single">1</Node>
            <PersonType>                                    1
                    <Name>Normal</Name>
                    <Probability>100</Probability>
            </PersonType>
    </Definition>

<Definition>
            <People>17</People>
            <Log>no</Log>
            <Node type="single">2</Node>
            <PersonType>                                    2
                    <Name>Normal</Name>
                    <Probability>100</Probability>
            </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```

Sample two

```
<EvacuatioNZ_Populate version="1.01">
    <Definition>
            <People>10</People>
            <Log>yes</Log>
            <Node type="single">1</Node>
            <PersonType>
                    <Name>Normal1</Name>
                    <Probability>50</Probability>           3
            </PersonType>
            <PersonType>
                    <Name>Normal2</Name>
                    <Probability>50</Probability>
            </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```

The next sample shows how the user can specify distributions for the number of occupants in each node. The number of occupants in each node can be fixed (label 4), like the two samples shown previously, or it can have a distribution (label 5). This current version only has two distributions to choose from, which are uniform and normal distributions. By specifying distribution, it will simulate an occasion when a room is at its maximum allowable density.

Sample three

```
Fixed :          <People>10</People>                        4

Distribution :   <People>
                     <Distribution type="uniform">
                         <Min>20</Min>                      5
                         <Max>30</Max>
                     </Distribution>
                 <People>
```

The next sample shows how to specify to allow a number of occupants to be randomly apportioned over a range of nodes (line 3 in label 6). The number of occupants can be fixed or generated from a distribution as before. Note that the node types in the previous samples are all single, which means the all the occupants are in a single node. The following example spreads 10 occupants randomly into nodes 1, 2 and 3.

Sample four

```
<Definition>
<People>10</People>
<Node type="apportion">1 3</Node>                            6
...etc
</Definition>
```

The last sample is very similar to Sample four. In this case, instead of “apportion”, “range” is used (line 3 in label 7). It means that same number of occupants are distributed in a range from 1 to 3, that is, node 1,2 and 3 each has 10 occupants.

Sample five

```
<Definition>
<People>10</People>
<Node type="range">1 3</Node>
...etc                                              7
</Definition>
```

(c) SIMULATION file

This file allows the user to set up some of the parameters for the simulation. These include the maximum simulation time (1), the time step (2), occupant density (3 and 5) and flow calculation. The user can specify any number for occupant density as long as it is practical and justified for each case. The maximum node density (3) is to determine the maximum number of occupants that are able to enter a node.

Furthermore, the user has two options for selecting door queuing correlations, the MacLennan door queuing correlation and the Holmberg door queuing correlation (refer to Teo (2001) for further information). Besides, the user can also select one of two approaches, the nodal density approach and the connection density approach. These have been discussed in Teo (2001). However, further findings were done and it is recommended that instead of using one of the approaches, a combination of the two approaches is more logical and realistic. It is known as “mixed” in label 5. This will be discussed later in Chapter 4. A sample of the SIMULATION file is shown below:

```
<EvacuatioNZ_Simulation version="1.01">
    <TimeMax>12000</TimeMax>                                          1
    <TimeStep>1</TimeStep>                                            2
    <MaxNodeDensity>2.00</MaxNodeDensity>                             3
    <DoorFlow>Maclennan</DoorFlow>                                    4
    <OccupantDensityModel localOccupantDensity ="3.0">mixed
                                          </OccupantDensityModel>     5
</EvacuatioNZ_Simulation>
```

(d) SCENARIO file

In this file, the user sets up the simulation for each scenario. The user specifies the number of simulations (1), which will produce a probabilistic result. This is where the Monte Carlo approach is adopted. Pseudo-random numbers can be produced using a table of random numbers built into the program.

To obtain the probabilistic results, the user will have to activate the dump evacuation time feature (2). It will produce a Microsoft Excel Comma Separated Values file (.csv) with all the evacuation times from the simulations. Moreover, there is a feature called the "random start" feature (3). This feature allows the occupants to be randomly distributed throughout their starting node. As a result, each occupant will have different travel distance and arrive at the door at a different time. The user has the option to either activate this feature or not. Nevertheless, activating this feature would simulate a scenario more realistically. Further information about the random start feature was discussed in Teo (2001). A sample of the SCENARIO file is shown below.

```
<EvacuatioNZ_Scenario version="1.01">
    <Simulations>2000</Simulations>                                 1
    <DumpEvacuationTimes>Yes</DumpEvacuationTimes>                  2
    <RandomStartPosition>Yes</RandomStartPosition>                  3
    <Files>
        <Simulation>simulation.xml</Simulation>
        <PostProcess>pp template.xml</PostProcess>
        <Populate>populate.xml</Populate>
    </Files>
</EvacuatioNZ_Scenario>
```

The above files describe the physical aspects of the model, which can be executed as a physical science model or a "ball-bearing" model as described in Section 2.4. The following two files describe the behavioural aspects of the model.

(e) PERSON TYPE file

This file defines what kinds of occupants in a population. The user can specify as many person types as the user desires. Each person type is specified with a name, a speed, an exit behaviour and a pre-evacuation time. The user specifies the maximum potential speed, and it is the maximum limit to the Nelson and MacLennan equations. Unless it is specified, the speed will be calculated using the above equations. The exit behaviour in this file is defined in the EXIT BEHAVIOUR file. For example, “Default” at line 3 in label 1 corresponds to the exit behaviour specified in label 1 in the EXIT BEHAVIOUR file.

The new addition in this current version is the pre-movement time. There are two types of distributions built in the program, a normal distribution and a uniform distribution. It is suggested that Weibull distribution is most suitable among other distributions, such as Polya (MacLennan et al., 1999), for the pre-movement time. These two distributions allow for testing of the program and are suitable approximations to more complex distributions for pre-movement time. The user can also omit the pre-evacuation time setting (label 2) if it is not required. A sample of the PERSON TYPE file is shown below.

```
<EvacuatioNZ_PersonType version="1.01">
        <PersonType name="Normal1">
                <Speed>1.20</Speed>
                <ExitBehaviour>Default</ExitBehaviour>
                <PreEvacuation type="distribution">
                        <Distribution type="normal">
                                <Mean>90</Mean>                                  1
                                <StandardDeviation>10</StandardDeviation>
                        </Distribution>
                </PreEvacuation>
        </PersonType>
        <PersonType name="Normal2">
                <Speed>1.20</Speed>
                <ExitBehaviour>Default</ExitBehaviour>
                <PreEvacuation type="distribution">
                        <Distribution type="uniform">
                                <Min>90</Min>                                    2
                                <Max>100</Max>
                        </Distribution>
                </PreEvacuation>
        </PersonType>
</EvacuatioNZ_PersonType>
```

(f) EXIT BEHAVIOUR file

The user can specify the type and probability of exit behaviours for the occupants. Exit behaviours correspond to the choice of escape routes exhibited by the occupant during the evacuation. Similar to the POPULATE file, it is very flexible and an exit behaviour can have any combination of exit behaviour types. For each exit behaviour type, a probability (line 3 in label 1) is assigned to it and a total probability will add to 100 percent (see label 1). The types of exit behaviours have been revised since the previous research and are currently integrated into the model. The newly incorporated behaviour is the choice of exit. The types of exit behaviours are as below:

- First route (First)

  In this exit behaviour, the occupants use the first path that is available to them. In a scenario where there are multiple paths, the occupants will choose the first path that they "see". This is common for occupants who are not familiar with the building. It may also be interpreted when there is limited visibility in the building due to smoke. The order of connections listed in the MAP file for the particular node will decide the order of paths that the occupants will see first. Nevertheless, the connection details will need extra care to construct due to the way this exit behaviour is specified. This exit behaviour needs further testing before it can be used with confidence.

- Minimum nodes to safe route (MinNodesToSafe)

  This route indicates the path that passes minimum nodes to reach a safe node. This means the occupants escape through minimum rooms, corridors or stairs to reach a safe place. However, it does not mean the route is the shortest distant from a safe place; on the contrary, it can be the furthest distant from a safe place. This exit behaviour is observed in occupants who know their way around the building. For example, if the occupants know there is a safe place at the end of a long corridor, they will use that route; while there is a second safe place where they will have to pass through a couple of rooms to reach it.

- Minimum distance to safe route (MinDistanceToSafe)

  This route means it is the minimum distance to a safe node. This is quite distinct from the minimum nodes to safe route. This route can pass many nodes before reaching a safe place as long as it is the shortest overall distance. This behaviour can be observed in conjunction with the minimum nodes to safe route in actual evacuation events.

- Preferred route (Preferred)

  This is the escape route that the occupants are familiar with. As discussed in Chapter 2, studies have shown that occupants prefer to use the familiar exits than the fire exits. These familiar exits are usually the entrances to the building, which also indicated that they tend to use the same way they come in. This exit behaviour is an important assumption in designing means of escape. With a sudden increase of use in that particular escape route, it would hold a great risk of exceeding its egress capacity. This behaviour has been incorporated into the model; however, it still needs refinement and validation for more complicated scenarios.

- Exit sign route (ExitSign)

  This is similar to the preferred route. It works the same as the preferred route, except it is the "exit sign" route. This behaviour is observed in the occupants who are not familiar with the building tend to follow exit signs. This behaviour has been incorporated into the model; however, it still needs refinement and validation for more complicated scenarios.

- Shortest path to next node(ShortestPathToNextNode)

  This behaviour indicates that the occupants can choose the shortest path to the next available node. This exit behaviour needs validation before it can be used with confidence.

- Random route (Random)

  This behaviour indicates that the occupants choose a path randomly from all the paths accessible to them.

- None (None)

  This means that the occupants remain in their current node, as they do not choose any of the paths.

It must be noted that the correct format of the exit behaviour type is in the bracket. If the format, for example the caps of the letter, is wrong, then the simulation will not the executed. A sample of the EXIT BEHAVIOUR file is shown below. It describes the exit behaviour named "Default" has two different behaviour types of equal probabilities, which means an occupant has two exit choices.

```
<EvacuatioNZ_ExitBehaviour version="1.01">
        <ExitBehaviour name="Default">
                <ExitBehaviourType type="MinDistanceToSafe">
                        <Probability>50</Probability>
                </ExitBehaviourType>                              1
                <ExitBehaviourType type="MinNodesToSafe">
                        <Probability>50</Probability>
                </ExitBehaviourType>
        </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

3.2.2 Output files

There are four output files for each scenario. These files are called: CONNECTIONS, LOG ACTION, NODES and LOG. They are generated in a Comma Separated Values file (CSV) that can be easily imported into Microsoft Excel, except the LOG file is in a text document. The text file records the detailed instructions on how the program is run, which also includes the evacuation times for each simulation.

The CONNECTIONS file records the number of occupants in each connection at each time step. This will show which paths are in less use or congested at a particular time or during the whole evacuation. The NODES file is similar to the CONNECTIONS file except it is in each node. It also helps to identify the potential bottlenecks in the building. The LOG ACTION file shows the percentage of the occupants in a wide range to events that are built in the program at each time step. Therefore, the percentage in each event should add up to 100 percent at each time step. These events are mainly the actions an occupant is likely to take, such as ignoring an alarm, starting to move, alerting or assisting other occupants and others. As the model is yet to complete, most of the events are not incorporated.

These three files are generated for each simulation. This enables the user to obtain a probability distribution of a flow of occupant at an exit. Furthermore, there are two optional output files from the POPULATE file and the SCENARIO file.

3.3 Simulex and EvacuatioNZ

Simulex and EvacuatioNZ models adopt different approaches. Simulex uses the fine network approach. It can easily produce a network plan of the building by importing drawings from commercial used CAD programs. The fine network approach can represents the geometry accurately. However, this approach usually consumes a considerable amount of computation time. The more complex the building, the longer it takes to compute.

EvacuatioNZ uses the coarse network approach. Although it increases the speed of computation, inputs of building dimensions for a complex building can be time-consuming. This is especially the case where a single node could not be justified. This can be seen later in Chapter 7 in a lecture theatre. It is also the case with long corridors in an office building. The user would have to divide the corridor into several nodes depending where each office room is located.

In terms of geometry, EvacuatioNZ is more flexible than Simulex. In EvacuatioNZ, the user can simply turn on or off a node or a connection when necessary. It is also easy to add or delete a node or a connection. In Simulex, the user would have to edit the floor plan using CAD programs before importing it to Simulex. If the overall floor area does not change, it would not cause any problems; otherwise, all the links and exits will have to move.

However, Simulex provides a visual display of the evacuation. This makes tracking the occupants and observing the movement much easier. It also enables the user to identify any bottleneck situation and rectify any problems during the simulation. Simulex takes into account of overtaking or other local interaction. The main problem encountered during the simulation is the occupants are trapped at links, or when two occupants trying to get through the narrow space like door. Tracking occupants and finding any flaws in EvacuatioNZ have proven to be a drawback, especially when there are a lot of nodes and connections.

Simulex produces an optimal result, whereas EvacuationNZ produces a probabilistic result. The latter prove to be more realistic. In reality, there is always an uncertainty on what situation the evacuees would be in. Therefore, designers and fire engineers would have to create a number of possible scenarios. For each scenario, Simulex would produce one result. However, one would question the reliability of the result. On the other hand, EvacuatioNZ produces a probability distribution of evacuation times from the repeated simulations. This allows the user to have an overview of what the possible evacuation times are, and some knowledge of the possible worst-case scenario. The user may also be interested in looking at the probability distribution of the flow of occupants entering a node, which unlike the evacuation time, the user has to manually extract the files and construct a probability distribution, and is very time-consuming if the number of simulations is high.

EvacuatioNZ will incorporate behavioural aspects. Currently, it has an exit choice feature. Studies have found occupants tend to escape using the familiar route, and as a result of that, many emergency exits are not utilised. This will enable the user to evaluate the use of particular exits. Both models do not include re-direction.

4. Component testing

The basic flow components in EvacuatioNZ have been validated and are working adequately well (Teo, 2001). Since then several improvements have been made after Teo's report. The component testing described in this report was done simultaneously with the running of the two evacuations.

Some features have been added in this version 1.01 prior to the two evacuation simulations. These features are the pre-movement time and exit choice (minimum distance to safe, preferred and exit sign routes). The changes can be noted in the previous chapter. In addition to that, testing was carried out on the combination of components to ensure the model was working properly. This chapter will discuss the general assumptions that are made to the simulation of the two evacuations.

4.1 Assumptions

Simple test scenarios were created to test the combination of exit behaviour components. The combination of these components under discussion are the "minimum distance to safe", "minimum nodes to safe" and "preferred" routes. Exit sign route was later incorporated in the program. These will be used later in the evacuation simulations. This version of the program was constantly improved during the testing.

When constructing the MAP file, it was uncertain how to define the length of a connection. Livesey et al (2001) stated that in a coarse network model, regulatory control such as maximum travel distance should not be ignored and the length should be selected accordingly to the building geometry. By selecting the maximum length, it is expected that the result will be more conservative. However, in the two evacuation simulations, the connection length from the start node to the next node would not make any difference because the occupants would be randomly distributed throughout their starting node, thus the dimensions of the node will determine their new effective travel distance. The remaining connections will be specified by the maximum distance.

The problem encountered in the previous version where the occupants travel at the maximum movement speed on the stairs has been corrected in this version. It was verified by a simple two-node scenario, which is from a stairs to an exit. In a node containing a low occupant density, the occupants are travelling at a speed lower than the specified maximum potential speed.

In regards to the occupant density, a new method has been added in EvacuatioNZ to simulate a more realistic situation and it is called “mixed density” approach. It combines nodal density and connection density, which have been discussed in previous research. Considering a simple two-node scenario, when the occupant density is low, both nodal and connection density approaches will yield at the same evacuation time as all the occupants will travel the maximum speed. However, in a high occupant density, either nodal density or connection density approach is appropriate.

Simulex has an accurate approximation in simulating the movement of occupants. This was verified by a simple two-node map connected by a door as shown in Figure 4.1. Table 4.1 shows the evacuation times for four different occupant densities. A room of 500m² (Scenario 1) is filled with 1003 people scattered evenly throughout the room. At the start of the evacuation, people moved towards the exit. Afterwards, people started to crowd around the exit and more than half of the people are still moving freely at the back. As the time goes by, the occupant density is getting denser until everyone has to wait and queue around the exit.

Table 4.1 shows Scenario 2, 3 and 4 had similar evacuation times. The percentage difference between Scenario 1 and Scenario 4 was approximately 6%. This indicates that in a situation where queuing is the dominant factor in the overall evacuation process, occupant density has no significant influence in the evacuation time. It is noted that Simulex is unable to adequately simulate an occupant density higher than 2 ppl/m² in specific situations (see Section 7.1.1).

Table 4.1: Summary results of occupant density testing using Simulex.

	No. of occupants	Room area (m^2)	Occupant density (ppl/m^2)	Evacuation time (s)
Scenario 1	1003	500	2.0	506
Scenario 2	1003	1000	1.0	537
Scenario 3	1003	2000	0.5	538
Scenario 4	1003	4000	0.25	539

Hence, the mixed density approach should be used in EvacuatioNZ. Scenario 1 was set up in EvacuatioNZ to verify an appropriate local occupant density. By changing the local occupant density in the SIMULATION file (label 5), the results of the evacuation time were compared with the earlier findings from Simulex. Table 4.2 shows that an occupant density of 3.1 ppl/m^2 is closest to the Simulex result (506 seconds). However, for the ease of future simulations, 3 ppl/m^2 will be used in the two evacuation simulations. This local density is also a good approximation as the percentage difference between Simulex result was only 4%. Examples of input files are included in APPENDIX A.

Table 4.2: Summary of EvacuatioNZ results.

	Local density (ppl/m^2)	Evacuation time (s)
Trial 1	3.0	528
Trial 2	3.5	459
Trial 3	3.2	498
Trial 4	3.1	515

It is noted that the typical occupant density and crowding density varied between certain groups of people and circumstances around them. The crowd density can be as high as 4 to 5 persons/m^2 (cited in Proulx, 2002). Therefore, occupant-crowding density should be selected accordingly.

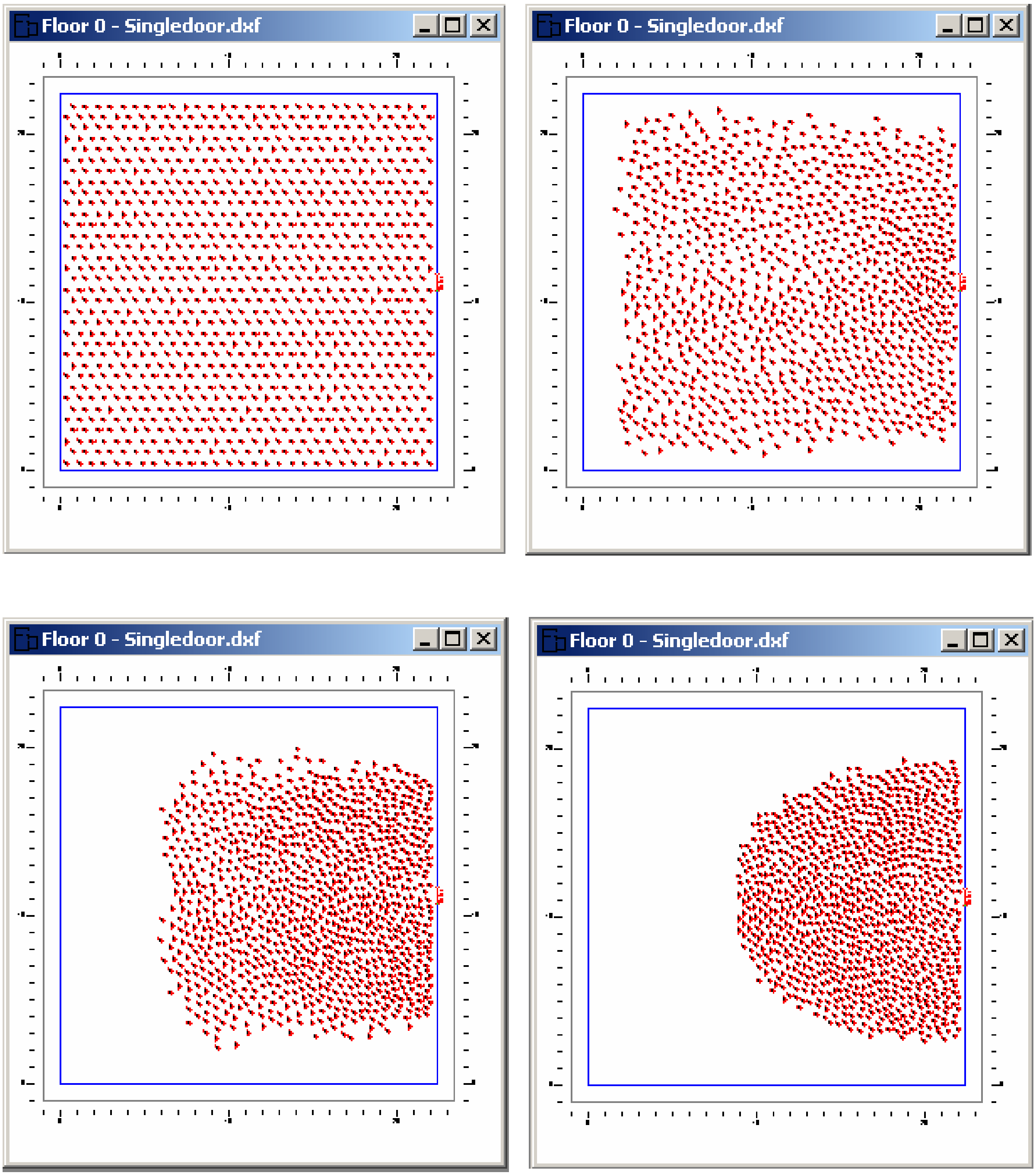


Figure 4.1: Illustrations of occupant densities

4.2 Combination of the exit behaviour components

After the above assumptions were made, tests were done on the combination of the exit behaviour components. Each behaviour mentioned earlier was tested individually first. A few networks of nodes were created to verify these behaviours. Examples of input files are included in APPENDIX A.

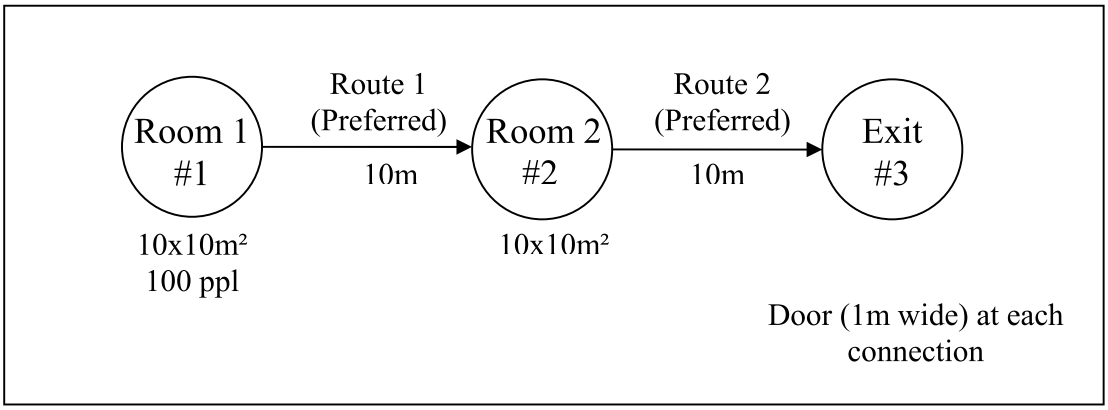


Figure 4.2: Nodal representation for the "Preferred" exit behaviour component.

Each node had the same dimensions ($10x10m^2$) and was connected by a door (1m wide). Depending on each different component, the connection lengths were different. Initially, only Room 1, Room 2 and Exit 1 were used to test the preferred route (Figure 4.2). In this scenario, only room 1 has occupants, and with the "random start" feature activated. In the MAP file, Route 1 and 2 were specified as the preferred route. However, there was a flaw in the algorithm. The problem was that when the occupants entered room 2, they were given a choice to go either Route 1 or Route 2 as both these routes were specified as the preferred route. Corrections were made to the algorithm so that when the occupants with this behaviour enter an intermediate node, the occupant would choose the shortest preferred route to the safe node, which is either Route 2 (10m) or Route 1 plus Route 2 (20m). This was to make sure that the occupant would not turn back.

The “minimum distance to safe”, “minimum nodes to safe” and “preferred” routes were tested using the network in Figure 4.2 and gave similar evacuation times of 75 seconds (approximated).

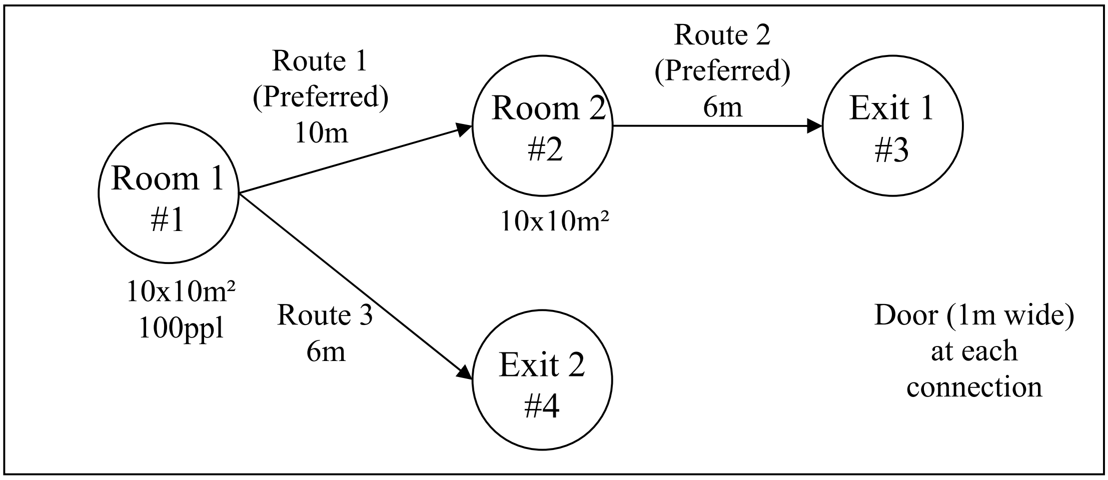


Figure 4.3: Nodal representation for the exit behaviour components.

A new exit was added as shown in Figure 4.3. It was also used to verify each of the three exit behaviours. Route 1 and 2 were the preferred routes. It was found that all three components were working properly. The “minimum distance to safe” and “minimum nodes to safe” routes both yielded the same result (approximately 50 seconds, all the occupants used Exit 2) and the “preferred” route yielded around 68 seconds as expected (all the occupants used Exit 1).

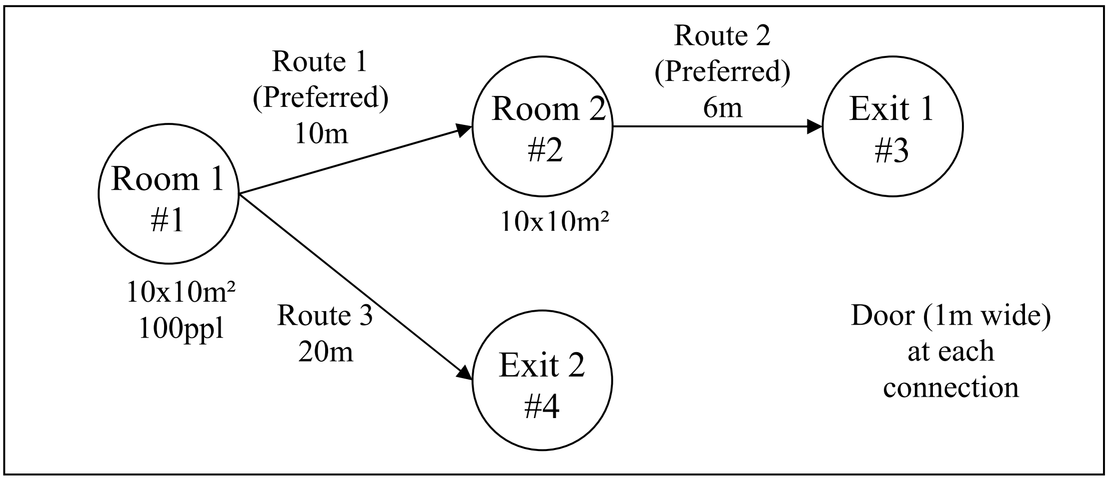


Figure 4.4: Nodal representation for the combined exit behaviours.

The connection lengths for Route 3 had changed as shown in Figure 4.4 in order to verify a mixed combination of all three behaviours, but only two at a time. The EXIT BEHAVIOUR file was written so that the occupants in Room 1 had two equal probabilities of either "minimum distance to safe" and "minimum nodes to safe" routes or "preferred" and "minimum nodes to safe" routes. The network in Figure 4.3 was also used for testing the "minimum distance to safe" and the "preferred" routes. All the combinations were working properly and the occupants used the routes as specified. These were verified by checking the output files. The evacuation times for using both exits (in Figure 4.4) were in between 43 and 50 seconds. It is noted that the occupants are in Room 1 only in the all the above mentioned scenarios.

The model was tested on the ability to accommodate more than one population. Using the network in Figure 4.4 again, another population (100 people) was added in Room 2. This was to see if there is any problem encountered when the occupants in Room 1 entered Room 2. The model was working properly under most situations, except the scenario shown in Figure 4.5.

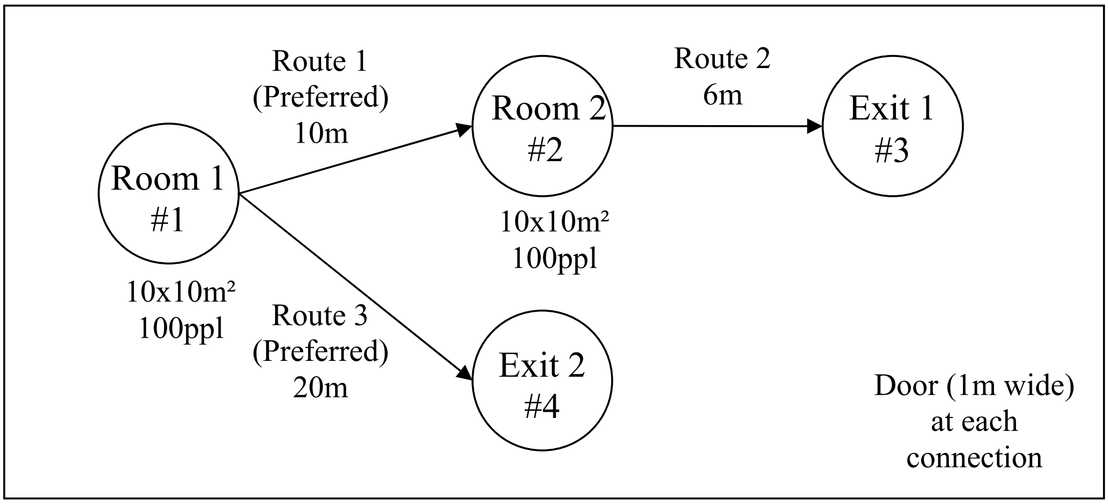


Figure 4.5: Problem test scenario.

This scenario describes the occupants in Room 2 had two equal probabilities of the "preferred" and "minimum nodes to safe" routes (one half goes to Exit 1 and the other half goes to Exit 2), while the occupants in Room 1 only had a choice, which is the "minimum distance to safe” route (Exit 1). Out of 10 simulations, only 5 simulations gave the desired outcome, which is the use of both exits. The number of occupants used Exit 2 ranged from 24 to 40 occupants; while the rest of the simulations showed no occupant used Exit 2. The latter simulations occurred every second run. Two problems were identified in this scenario. One would be the flaw in the simulations where no occupant used Exit 2 and the other would be the “preferred” route. The reason for the former problem is yet to be determined. It is noted that these problems also occurred in the lecture theatre evacuation simulations described in Chapter 7. Although the number of occupants that used Exit 2 was not close to 50 occupants, the model was working logically. The reason was that when the occupants entered Room 1, they had two preferred routes to choose from (similar to the problem mentioned before); therefore, some of the occupants would choose Route 1 instead of the supposed Route 3, which would result in other than 50 occupants.

There were some flaws in the preferred route algorithm. The problem in this network is that there was more than one safe node. It was observed that in some simulations there might still have occupants moving back and forth between nodes. The way the previous correction was made would work only under that scenario. Therefore, this component still needs more adjustments so that it would work properly under more complex networks. One of the adjustments should be made to the MAP file so that the preferred route can be specified as a one-way path.

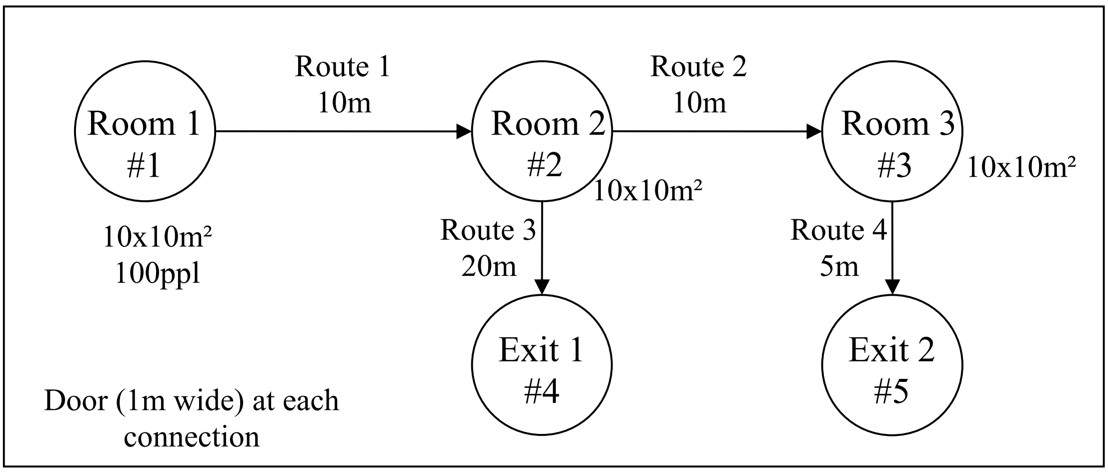


Figure 4.6: Another nodal representation of the test scenarios

Similar verifications were done using the network in Figure 4.6. The only problem encountered during the testing was the flaw in the order of creating more than one exit behaviour. From the example shown below, the program was only able to run when “Preferred” was written first (label 1), but not the other way round. The program should be able to work properly in any order how the two attributes are specified. It should work both ways.

```
<EvacuatioNZ_ExitBehaviour version="1.01">
        <ExitBehaviour name="Default">
                <ExitBehaviourType type="Preferred">
                        <Probability>50</Probability>          1
                </ExitBehaviourType>
                <ExitBehaviourType type="MinNodesToSafe">
                        <Probability>50</Probability>          2
                </ExitBehaviourType>
        </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

Although the input files can be written in a flexible way, care must be taken to ensure that it is fully incorporated in the program. It must be noted that this version of the model is revised so that it is able to work satisfactory in the two simulated evacuations. Because of this, there are some limitations on the use of this version, which are discussed earlier. Although the “preferred” exit behaviour components do not work as expected in some test scenarios, generally, the model does work properly and the basic flow components of the model are working satisfactorily.

5. Trial evacuation at PDL site

It is required in New Zealand that buildings should have evacuation schemes and a trial evacuation is conducted bi-annually. This trial evacuation came about while the author was doing an evaluation on the fire safety measures at industrial premises in Christchurch, New Zealand. Permission was given to collect information on this evacuation for this research. The evacuation was performed as an unannounced evacuation. None of the staff was informed beforehand, except for a few who were involved in conducting this evacuation. An exercise was done during the evacuation and it involved collecting data of occupants moving through exits. The alerting devices in the buildings are fire alarms (sounders).

The evacuation was performed in 2002. The drills went off an hour before noon on a fine day, which was just before lunchtime. Therefore, the evacuation was carried out at the maximum occupants' capacity and the staff would also be in a normal working environment.

5.1 Building descriptions

The evacuation took place at PDL Industry Ltd. The site comprised of offices, operational factories and warehouses. The offices are mainly two-storey buildings and the other factories and warehouses are single storey buildings. There are also a few empty buildings. Plans of the site were shown in Figure 5.1. Roads or streets surround the boundaries of the site.

In Figure 5.1, the areas of interest that were under discussion in the research are: A, C, E, G, J, H and L on the ground floor; U, S and G on the first floor. J, G and those on the first floor are offices, while A is a storage unit, C and E are assembly and processing areas, H and L are moulding areas. There are offices for customer service at the front part of E, behind J. The open area between J and E will be called a courtyard and the areas between J and G, and E and H will be called corridors further in the analyses. The approximate dimensions of these areas are: from the side edge of A to L is 134m and from J to E is 80m.

J is a reception area; it has a meeting room (museum) and an open waiting area. It can be accessed by the front entrance and the backdoors. It is directly connected to the first floor U by staircase. All the offices on the first floor are interconnected by doors. There is also a staircase connecting S and G. F can be accessed by internal and external staircases. The internal is connected to E and the external will reach the corridor in between E and H.

There are two entrances along the corridor to E. The front part of E is customer offices and a workshop. These can be accessed by an entrance facing the courtyard. The back part of E is a processing and packaging area. There are two separated swing doors connected to C from E and similarly, from C to A. There is a café at the corner of C. Similarly, there are two entrances to H along the corridor and two doors connecting from H to L.

Some interconnected doors or passages are somewhat used during the working hours and are irrelevant to an emergency use. A more detailed plan is included in APPENDIX B. As the site mostly comprises of factories and warehouses, there will be many products lying around in these areas. These can be seen later in Chapter 6 where the visual display in Simulex shows a general layout of the whole site based on the knowledge of the author.

5.2 Exercise

An exercise was carried out during this trial evacuation. The exercise involved eight observers standing near the main exits and recording the number of occupants coming out those exits. It is noted that these observers did not in any way affect the evacuation process or disturb the movement of the occupants. The observers also monitored the behaviour and the movement of the occupants. They were instructed to record the occupants coming out from the buildings as well as wardens. They also noted the start and the end of the alarms.

Table 5.1 shows where the exits were monitored. These exits were chosen based on the general knowledge and familiarity of the site. There are three evacuation control points on the site. These control points are included as the monitored exit. Exit 1, 2 and 6 led to a control point, that is, across the road. Exit 3 and 7 are the other control points. These exits will be regarded as safe exits. The monitored exits are circled in Figure 5.1. Although the exercise did not cover all the exits, the data collected can be assumed to include most of the occupants that day because those other exits mainly were located in the empty buildings.

The number of occupants coming out through the exit was entered in a data logger. This would provide valuable information on the flow of the occupants at that exit. After the evacuation ended (alarms lasted about four and a half minutes), all the observers got together to note down any actions or responses of the occupants during the evacuation.

Table 5.1: Descriptions for each exit and their usage

Exit 1: Main entrance at the Reception area (J) and first floor office area (U)
Exit 2: Entrance to one of the office area (G)
Exit 3: Exit for operational and storage area (A) -- evacuation control point
Exit 4: Main exit for the factory and the packaging area (C and E)
Exit 5: Alternative exit to Area C and E
Exit 6: Evacuation control point
Exit 7: Evacuation control point
Exit 8: Fire door exit for the factory (C)

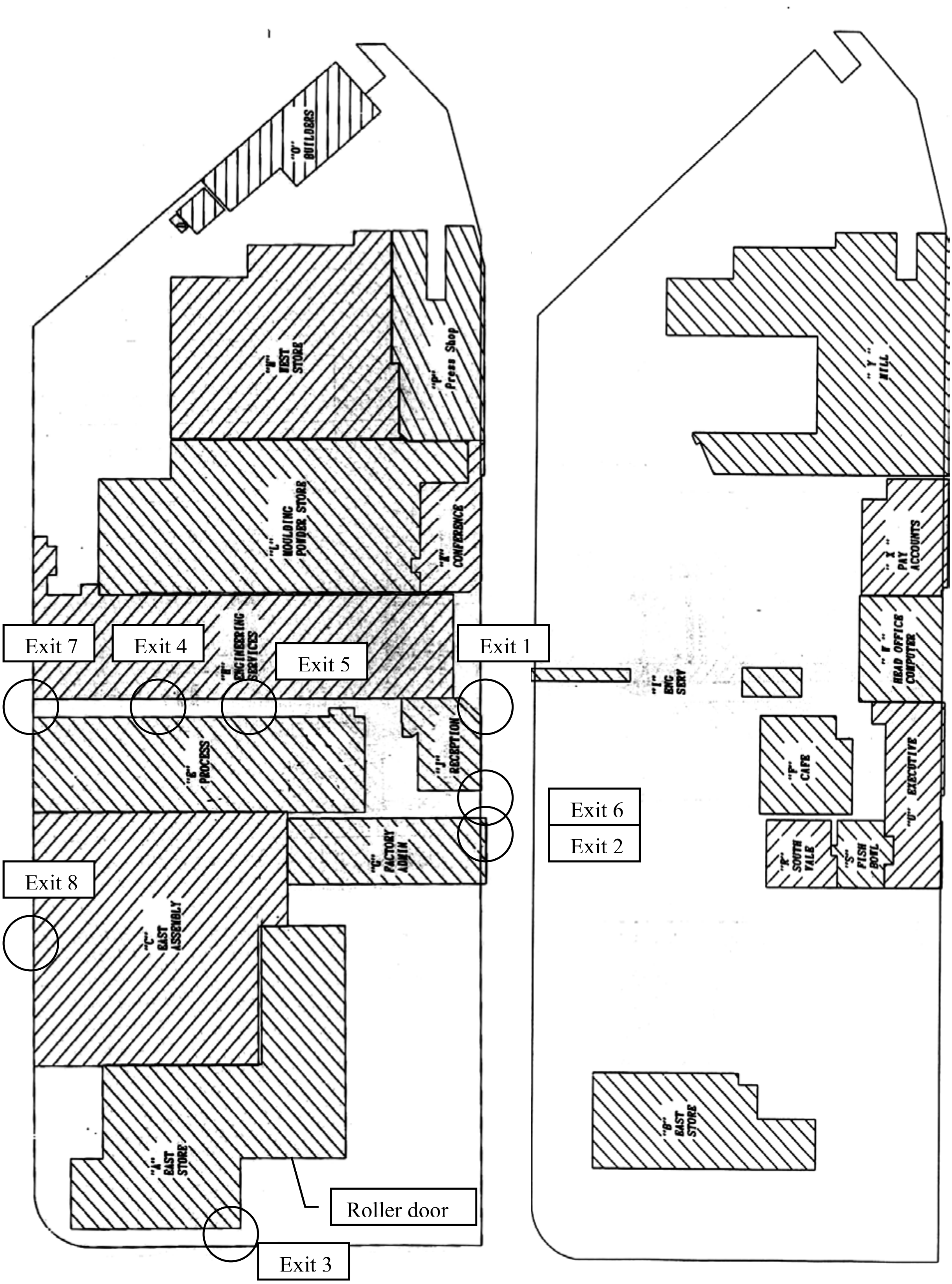


Figure 5.1: Plan View of the PDL Industries - Ground floor (left) and First floor (right)

5.3 Observations

- Generally, the occupants seemed very at ease. Occupants are generally adults, approximately even in proportion between male and female.
- Some occupants carried personal belongings such as bags, while others did not.
- Two occupants re-entered the building at Exit 1.
- One occupant was seen re-entering half-way through the evacuation at Exit 3.
- There were a few occupants coming out from the roller door instead of the exit door around the corner at A.
- At Exit 4, there were wardens going in to check and one occupant was seen coming out from Exit 4 soon after the alarm stopped.
- There was only one occupant coming out from Exit 5 and wardens were seen bypassing Exit 5.
- Wardens were seen at all exits, except Exit 6. They went in and out of the building several times when most of the occupants were evacuated.
- No occupants came out from the fire exit at Exit 8.

5.4 Results

Some observers had entered some useful information during the evacuation. They had indicated wardens and the occupants who re-entered the building. Table 5.2 shows the total number of people coming out from the exits and the time when the last person reached the exits. However, the data obtained at Exit 5 is not analysed as it was irrelevant. It was noted by the observer that only one occupant came out from that exit at the beginning when the alarm went off and the other occupants (that would be 9 of them) recorded were wardens bypassing the exits.

The average evacuation time at the safe exits, which are all the exits except Exit 4 and 5, was 142 seconds (2 minutes and 22 seconds). Exit 4 has the longest evacuation time. The reason is that one occupant came out from the building as soon as the alarm stopped where almost all the others left before 140 seconds. This can be greatly related to human behaviour aspects. It should be noted that the observer at Exit 7 was also recording the occupants coming out from Exit 4 and Exit 5. It was obvious that the information given by the observer at Exit 5 shows there was no one from Exit 4 or any exit beyond Exit 5 used the escape route to Exit 6 and vice versa. It also indicated that the occupants in F used the external staircase and chose to exit by Exit 6.

Table 5.2: Results from the trial evacuation at PDL.

	Number of people	Time [s]
Exit 1	28	217
Exit 2	21	100
Exit 3	26	155
Exit 4	92	257
Exit 5	10	86
Exit 6	54	93
Exit 7	127	145

Figure 5.2 and Figure 5.3 describes the cumulative percentage of the occupants evacuated at each exit. The graphs were plotted at the start of the alarm and the dotted vertical line indicated the end of the alarm. The diamond-shape data point represents each observation of occupants coming out from each exit. The hollow diamond-shape data point represents a warden. The light diamond-shape data point in Exit 1 represents an occupant re-entering the building.

By comparing both the office evacuation times, which are Exit 1 and 2, there was about 50% difference. However, in Figure 5.2, about 80% of the occupants from Exit 1 evacuated at 100 seconds. Therefore, the huge difference in the total evacuation time is mainly due to a small proportion of occupants responding slowly.

From both Figure 5.2 and Figure 5.3, the time for the first occupant to leave was around 20 to 30 seconds. The majority of the occupants, which is approximately 70% to 100%, left around 90 seconds. Wardens were seen around 90 to 150 seconds and usually there were remaining occupants following close by. It was found that overall evacuation time is mainly governed by Exit 7, which also recorded the maximum number of occupants.

Generally, the occupants responded pretty well in this trial evacuation, although a small proportion of the population had a different response to the majority. It should be noted that most of the occupants might have experience or possess knowledge of evacuation procedure, which would eventually result in faster evacuation time. Furthermore, there are a few preferred exit choices, such as, almost every occupant in C and E chose Exit 4. Some assumptions will be made in regards to this evacuation later in Chapter 6.

Refer to APPENDIX B for raw data obtained from the exercise.

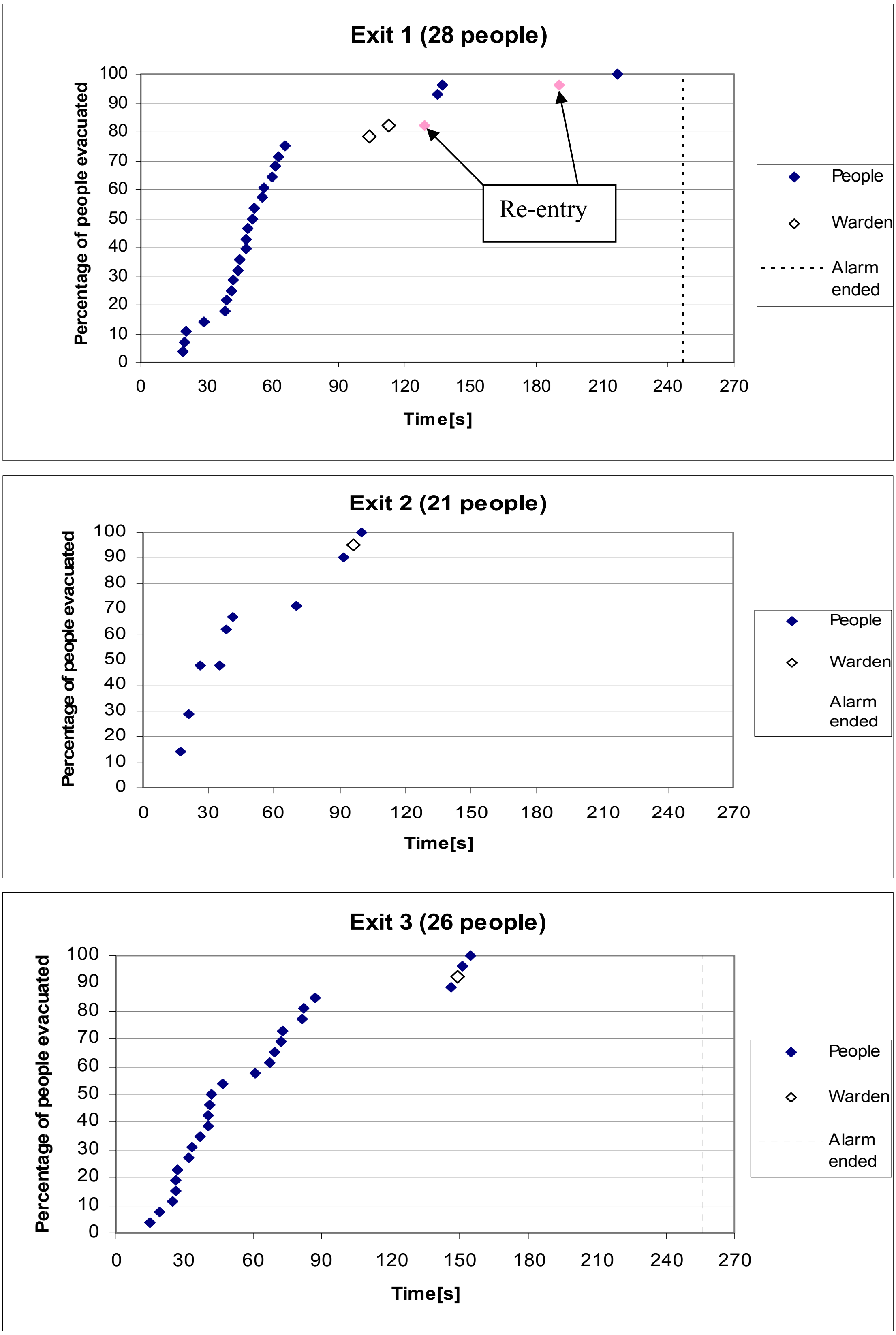


Figure 5.2: Results from the PDL trial evacuation for Exit 1, Exit 2 and Exit 3

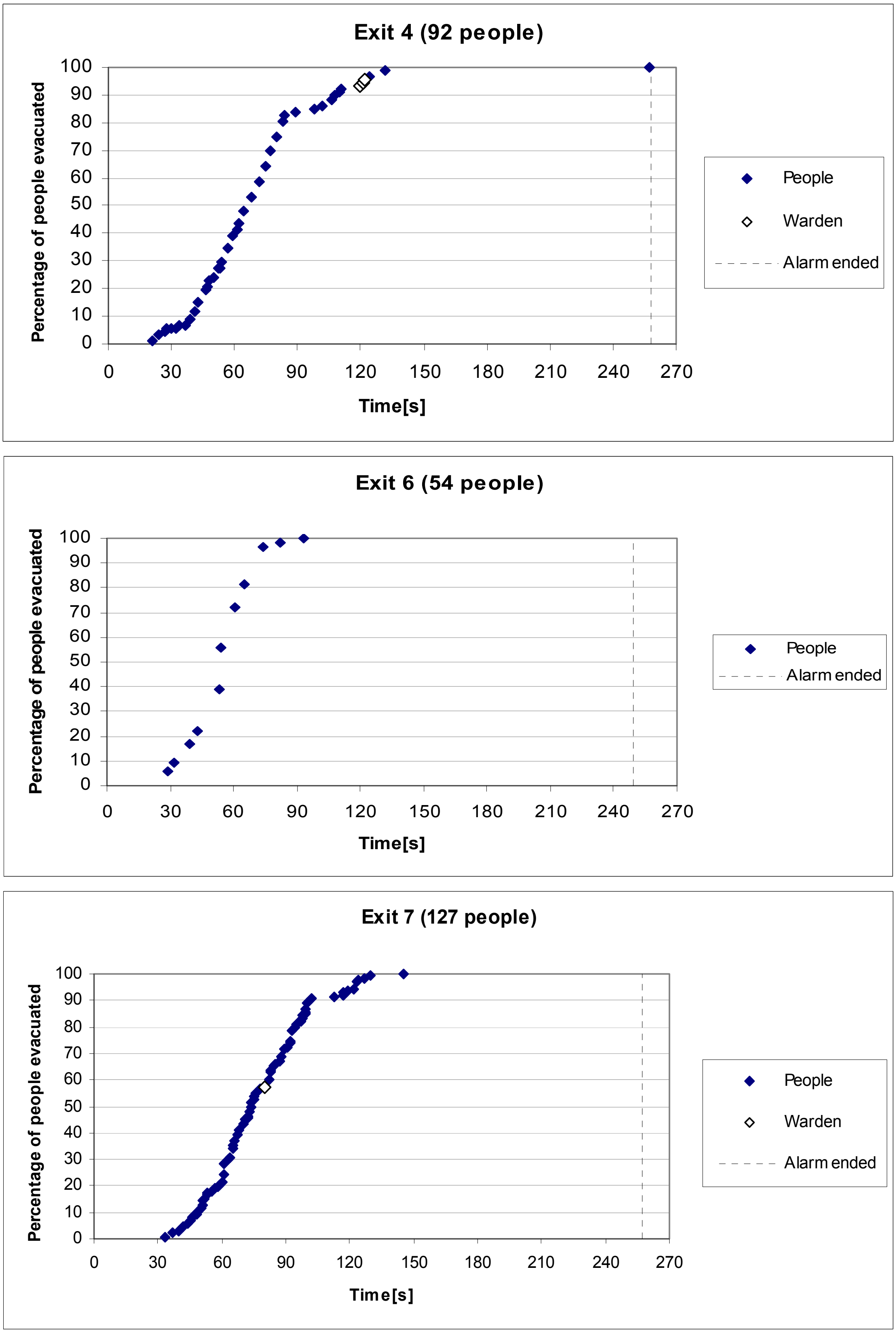


Figure 5.3: Results from the PDL trial evacuation for Exit 4, 6 and 7

6. Analysis on industrial premises evacuation

In this chapter, the PDL evacuation is simulated using Simulex and EvacuatioNZ. The inputs of the simulations were based on the available data and the general information of the site, which were mentioned in Chapter 5. The general layout, including the placing of the products and equipment, can be seen in the visual display in Simulex (Figure 6.2 and Figure 6.5). The geometry of the site was estimated based on site measurements and available drawings (refer to APPENDIX B). All the relevant materials to this chapter are included in APPENDIX C.

6.1 Modelling with Simulex

6.1.1 Methodology and assumptions

The site was modelled into four different parts. Based on the general evacuation procedure for the site, Table 6.1 shows which exits would be used by occupants in which area. The occupants in L and H would go the nearest exit depending on which end of the area they are in. Because the buildings are mainly interconnected, there are other routes to the exits that the occupants might use (depending on where the occupants were at the time of alarm). Assumptions of exit choice were made in the simulated scenarios based on Table 6.1. Therefore, most of the areas were modelled independently as it was assumed that there is no interconnected link between those areas, particularly between C and A.

The ground level was modelled using four different plans. The first level was modelled using only one plan. Each plan has two to three scenarios. In these scenarios, assumptions were applied to those included the position of occupants and the pattern of their escape routes. Furthermore, mean response times (same as pre-movement times) of 30 and 60 seconds were assigned to the office building. This response time was based on the findings by Proulx and Fahy (1997).

Table 6.1: General evacuation procedure for PDL site.

Area	Exit used (Referred to Table 5.1)	Number of occupants
C and E	Exit 7	92
A	Exit 3	26
G and S	Exit 2	21
Front part of E and F	Exit 6	12+26
J and U	Exit 1	28
H and L	Exit 6 and Exit 7	55

The number of occupants in each area was based on Table 5.2. It was assumed that all those occupants (including wardens) were in the areas under discussion at the time of alarm. It is noted that the number of occupants recorded at Exit 7 would include occupants from C, E, partly L and H. From the observations mentioned in Chapter 5, one occupant was assumed to used Exit 5 instead of 10 as recorded. As only the occupants in A used Exit 3, it was assumed that A has 26 occupants. C and E have 92 occupants overall, including the one that used Exit 5. Area G plus S and Area U plus J have 21 and 28 occupants respectively. The rest of the area (front part of E, F, H and L) would make up for the rest of the occupants. H and L would have about 55 occupants overall, 26 people in F and 12 people in the front part of E. The overall numbers of occupants were different in some scenarios; however, the difference has no significant effect on the evacuation time.

As mentioned previously, the ground level was modelled using four different plans. Figure 6.1 shows Plan 1, which only consisted of J, C and E (including the customer service office and workshop). The shadowed areas indicate obstructions such as tables, pallets of products, machinery and others in the factory and offices. This is to represent a more realistic movement along an escape path. There are four exits in the plan, which are Exit 1, 2, 6 and 7. Figure 6.2 shows the first level that consists of F, U and S.

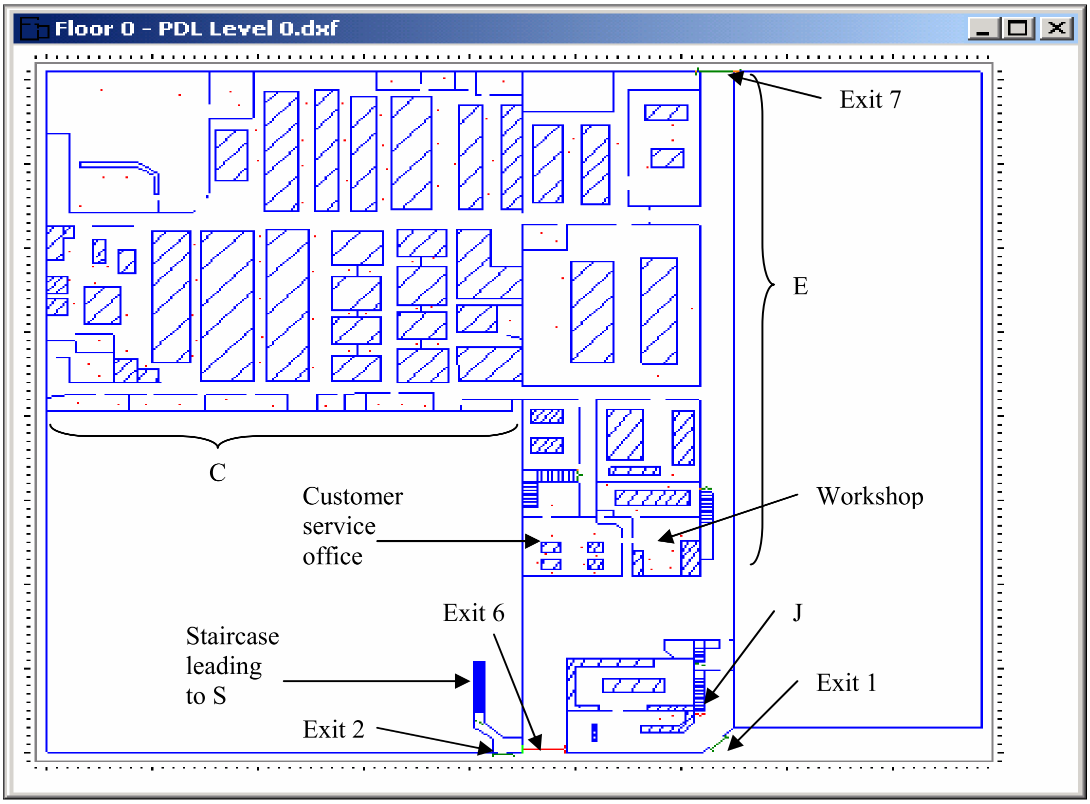


Figure 6.1: Ground level of PDL-Plan 1(C, E and J; Exit 1, 2, 6 and 7)

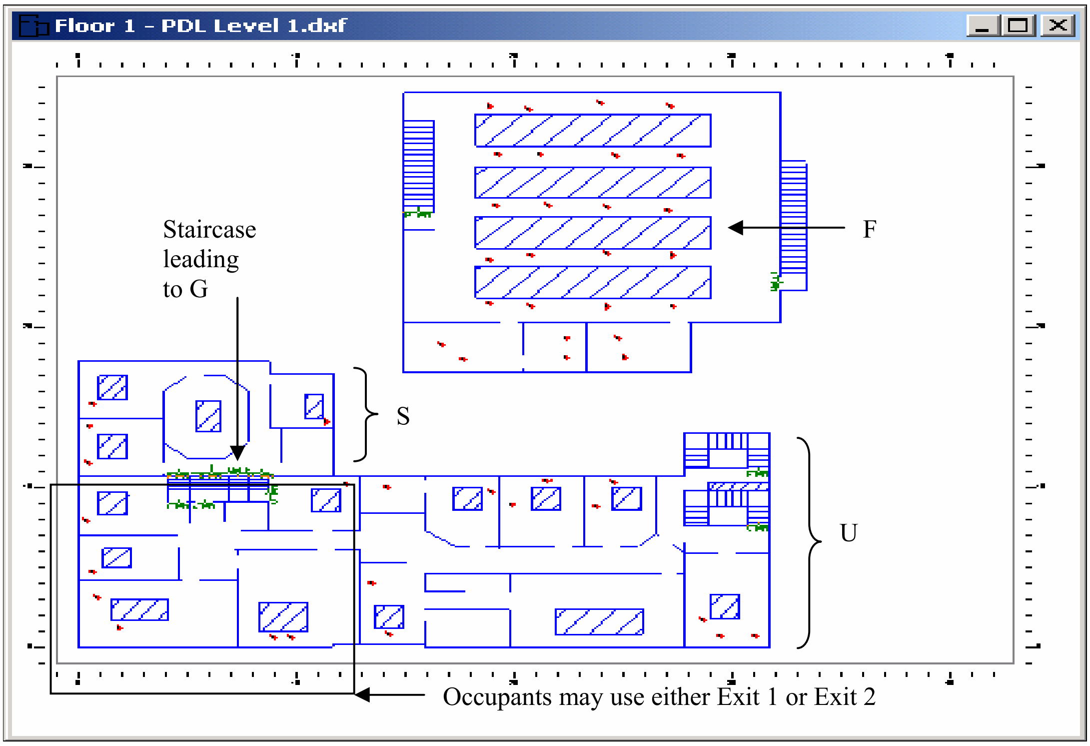


Figure 6.2: Level 1 of PDL (F, U and S)

The occupants were randomly distributed on the plans, taking into account the general usage of the areas during the normal working hours. Two scenarios were conducted based on this model. Initially, it was found that by using the default distance map (the occupants are assumed to choose the shortest path to the nearest exit), the occupants from F went through the back door of J and exited by Exit 1, which is certainly not what the evacuation procedure indicated. Therefore, in those two scenarios, a new distance map was assigned only to the occupants in F so that they would not use Exit 1. The difference in each scenario is the choice of exit used by the occupants in U. About half (circled in Figure 6.2) the occupants in U were assigned to use Exit 2, the other half Exit 1; whereas in the other scenario all the occupants in U used Exit 1. The default distance map was used in the remaining areas. The former is Scenario 1a and the latter is Scenario 1b. The default setting was used for the response time, which is a random distribution with a mean of one second. It means that there was no pre-movement time.

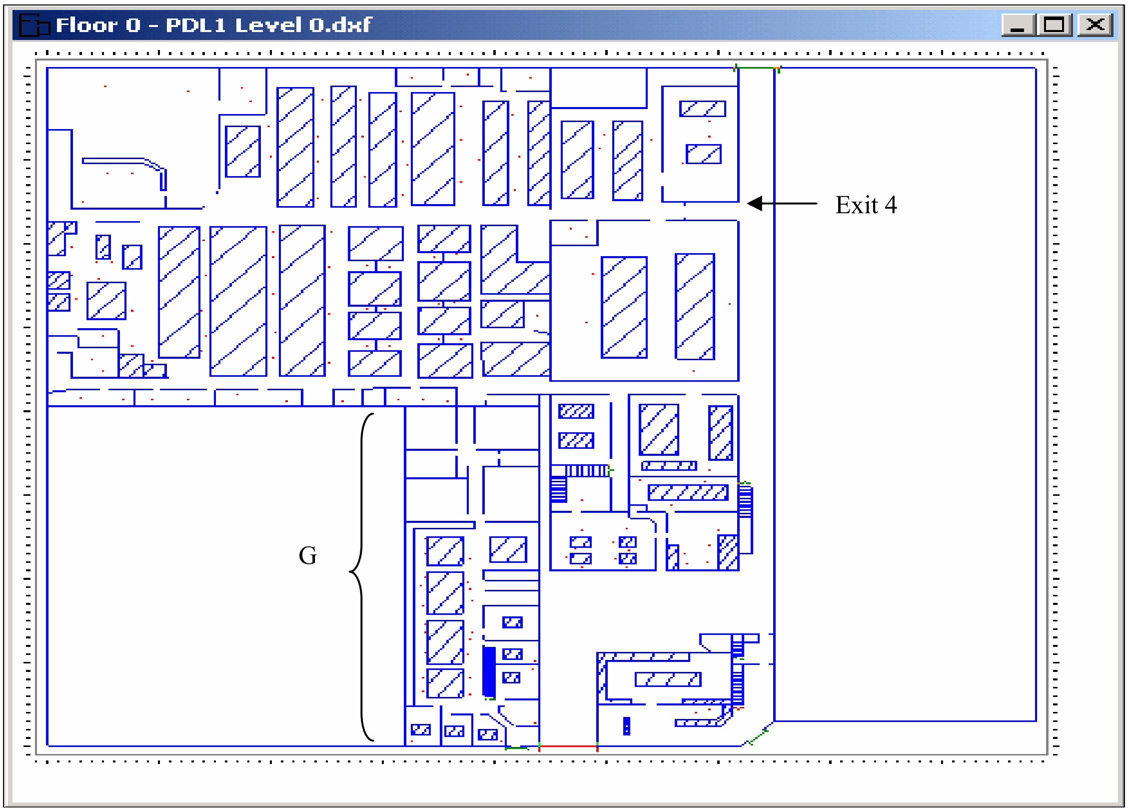


Figure 6.3: Ground floor of PDL-Plan 2 (G)

Figure 6.3 shows an additional area was added to Plan 1, which is G. This is used to show how the occupants from upstairs (S) interacted with the occupants moving downstairs (G). The positions of the occupants in other areas remain the same as in Figure 6.1.

Similar scenarios were used as described in Scenario 1a and 1b. The only difference is the addition of the occupants from G. Furthermore, a third scenario was created. In this scenario, an exit was added in Plan 2 at where the Exit 4 was. This is to compare the flow of occupants in Simulex with the actual trial data. The first two scenarios are labelled as Scenario 2a and 2b, and the third Scenario 2c. No response time is used in these three scenarios as well.

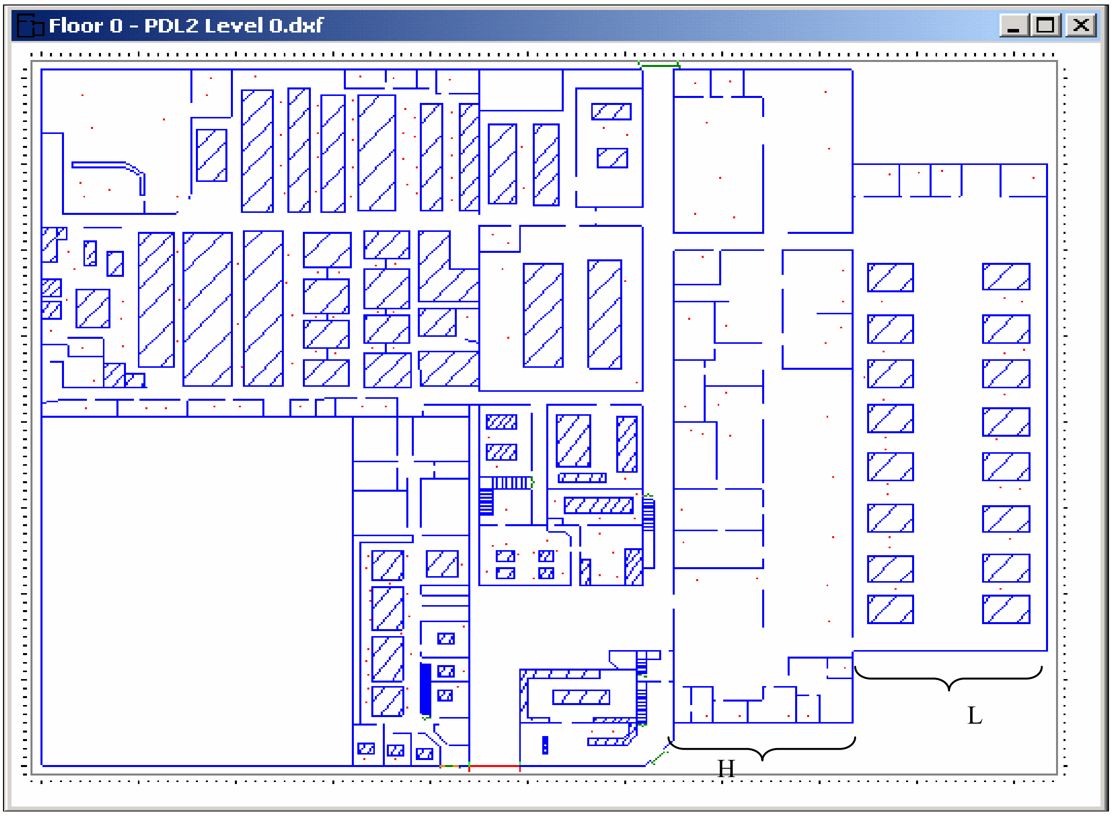


Figure 6.4: Ground floor of PDL-Plan 3 (H and L)

Figure 6.4 shows more manufacturing areas, which are H and L, were added to create Plan 3. With the additional areas added, the number of occupants at Exit 6 and 7 would increase and the flow rate would differ. The positions of occupants in other areas were similar to the other plans. The same scenarios in Plan 2 were simulated in Plan 3 and these are Scenario 3a, 3b and 3c respectively.

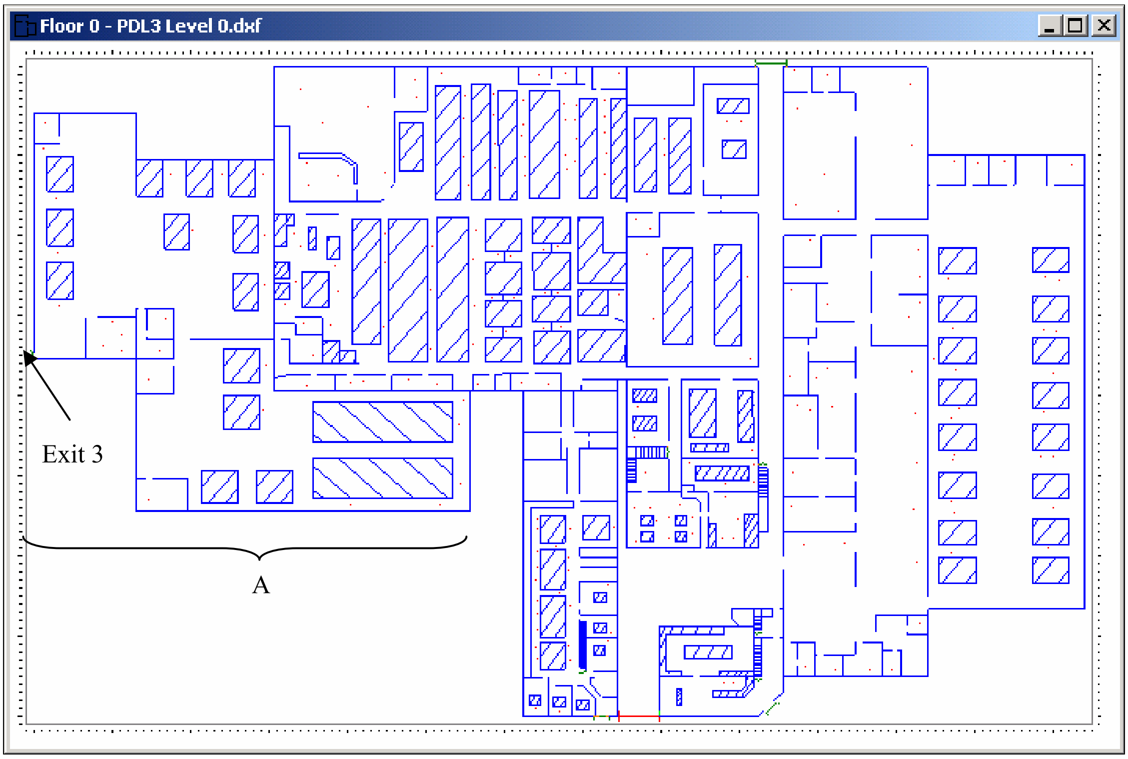


Figure 6.5: Ground floor of PDL-Plan 4 (A and Exit 3)

Figure 6.5 represents the overall ground level of PDL site. One additional exit was added at A to represent Exit 3. It should be noted that the number of the occupants in U, G, H and L in the scenarios above are not representative to the actual trial data. A scenario was created to represent the actual event so that the number of occupants at each exit is close to the recorded value. In this scenario (Scenario 4a), all the occupants in U would use Exit 1, which is similar to Scenario 1a, 2a and 3a. In addition, two more scenarios were created similar to Scenario 4a, but with a response time. The mean response time of 30 seconds and 60 seconds were assigned to the office areas (G, J, U, S and F) in these scenarios respectively. The former is Scenario 4b and the latter is Scenario 4c.

Table 6.2 shows the all the scenarios performed for the PDL evacuations in Simulex. In all the scenarios, the default distant map was used for every area except F, unless otherwise stated in the scenarios. The "office staff" person type was selected, as it is more appropriate than the other types. It comprises 30% females, 40% males and 30% average body types.

Table 6.2: Summary of the scenarios for PDL in Simulex

*	Plan used	Remark
Scenario 1a	Plan 1	Allocate each 'half' of the occupants in U to Exit 1 and Exit 2 respectively.
Scenario 1b	Plan 1	Allocate all occupants in U to Exit 1.
Scenario 2a	Plan 2	Allocate each 'half' of the occupants in U to Exit 1 and Exit 2 respectively.
Scenario 2b	Plan 2	Allocate all occupants in U to Exit 1.
Scenario 2c	Plan 2	Additional exit at Exit 4.
Scenario 3a	Plan 3	Allocate each 'half' of the occupants in U to Exit 1 and Exit 2 respectively.
Scenario 3b	Plan 3	Allocate all occupants in U to Exit 1.
Scenario 3c	Plan 3	Additional exit at Exit 4.
Scenario 4a	Plan 4	Allocate all occupants in U to Exit 1.
Scenario 4b	Plan 4	A response time of 30 seconds in G, J, U, S and F.
Scenario 4c	Plan 4	A response time of 60 seconds in G, J, U, S and F.

* '1' represents Plan 1; '2' represents Plan 2 and so on. 'a', 'b' and 'c' each represents a different situations.

6.1.2 Results

Figure 6.6 and Figure 6.7 are the visual displays in Simulex identifying the bottleneck areas which are the circled areas. Circle 5 in Figure 6.7 has the most serious bottleneck situation. This circled area shows that the pathway from the bottom of the stairs to Exit 2 is narrow and creates a problem during an emergency evacuation when the occupant load is high. Occupants from upstairs are also one of the main factors that caused the bottleneck situation, as their descending to G would cause further disturbance in the flow.

The observations from the exercise indicated that all the occupants in C and E used Exit 4. This was also observed from all the simulations in Simulex. The occupants in F and in the front part of E followed the route to Exit 6 as anticipated in Table 6.1; whereas around half of the occupants in the H and L used either Exit 6 or Exit 7, depending on the location of occupants.

The flows of the occupants and the evacuation times were almost identical at each exit This is because Simulex would produce the same results when the characteristic of the occupants remained unchanged in some scenarios.

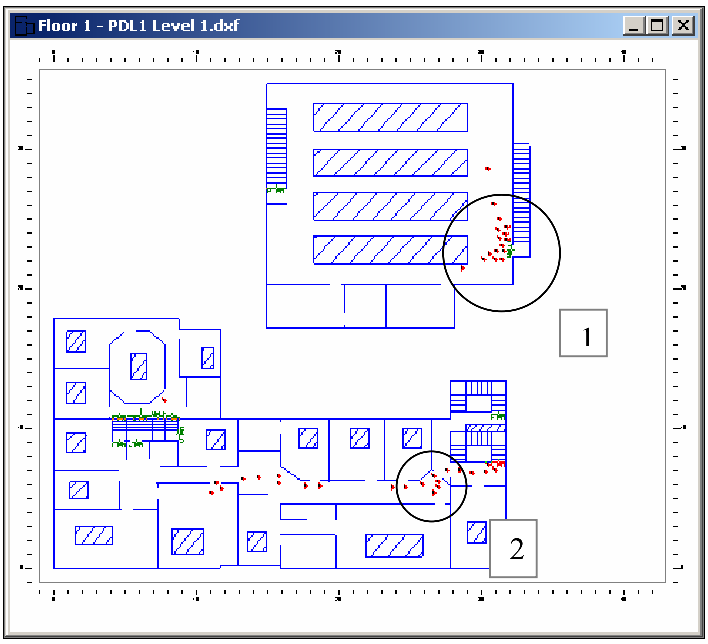


Figure 6.6: Bottleneck areas at level 1 of PDL.

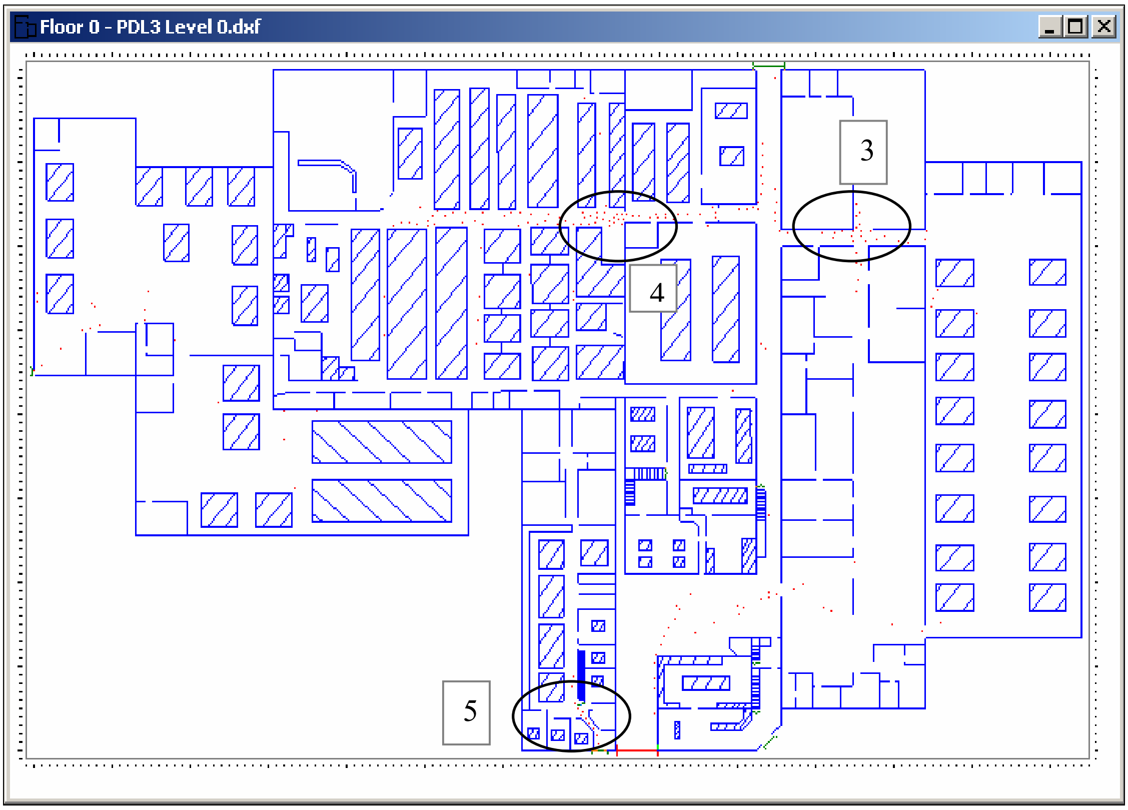


Figure 6.7: Bottleneck areas at ground level of PDL.

6.1.2.1 Without pre-movement time

All the figures in this section show the flow of the occupants at each exit without any pre-movement time. The graphs were plotted from the start of the alarm until the last occupant evacuated. It should be noted that the figures only show the scenarios that are relevant to each exit. Similar results were omitted for clarity.

Figure 6.8 shows the flows of each scenario was almost the same. The flow rates of Scenario 1b and 4a were similar to the actual trial data until around 60 seconds. The difference between these flow rates were about 5 to 10 seconds. Similarly, the flow rates of both scenarios at Exit 4 were also a good match compared with the actual trial (Figure 6.9), with a gap of 20 seconds difference. However, the overall evacuation times were different. This is because a small proportion of the occupants had a different response after hearing the alarm and created long tail (circled in the graph).

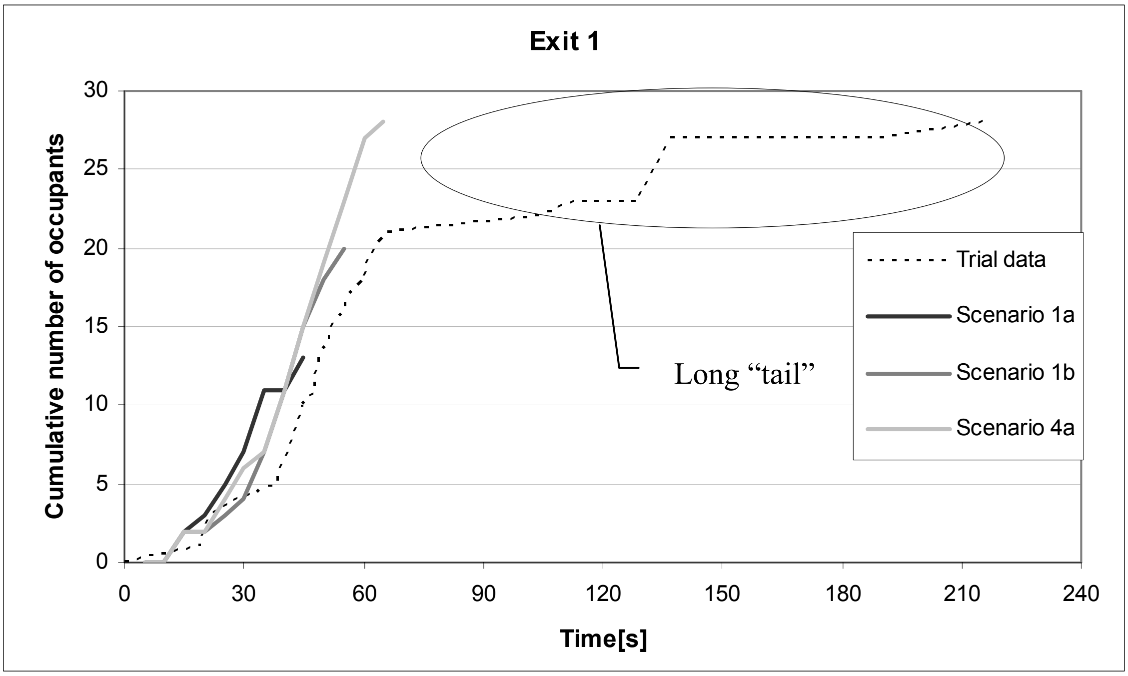


Figure 6.8: Results from Simulex for Exit 1

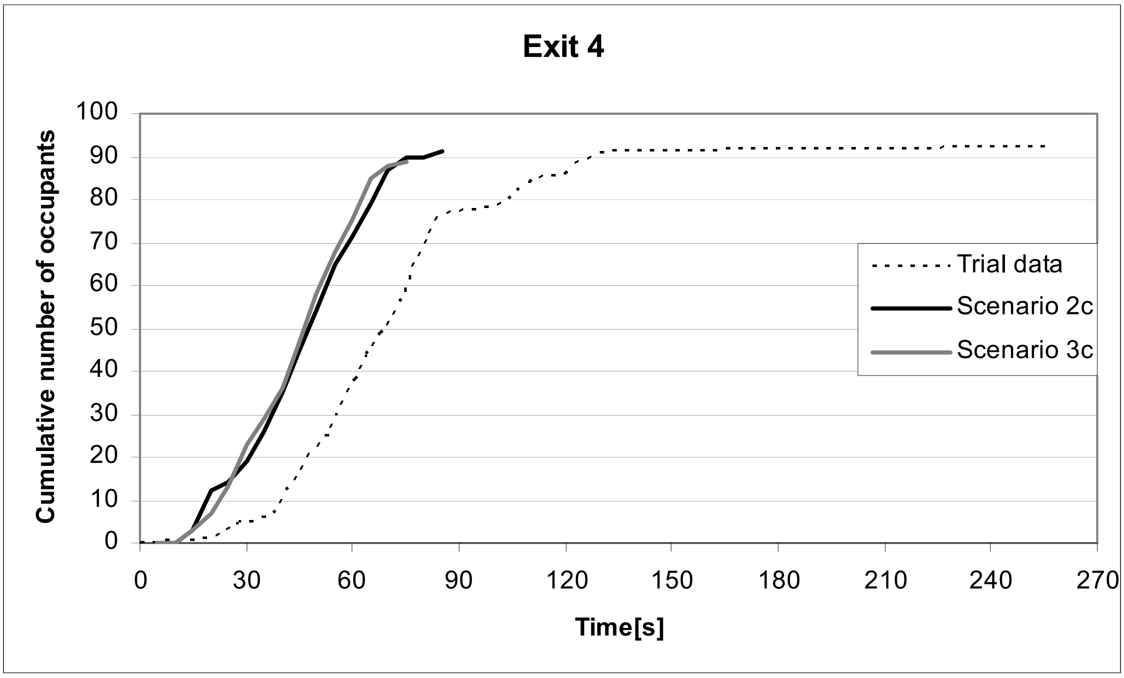


Figure 6.9: Results from Simulex for Exit 4

There is also a significant difference in the evacuation times in Exit 2 as shown in Figure 6.10. The flow rate changed dramatically throughout the actual evacuation. This indicated that the pre-movement time is different for each individual and thus the long tail. Similarly, the Simulex results at Exit 3 showed faster evacuation time and higher flow rate compared with the trial data (Figure 6.11).

Figure 6.12 shows that the simulated evacuation times at Exit 6 were not far away from the actual data, that is, no obvious 'tail' in the graph. The flow rate of Scenario 3a showed a rather similar pattern to the trial data. The trial data indicated that there was a sudden increase of flow at around 50 seconds. This may be due to the merging of the occupants from H and F (observed from Simulex visual display). The results also showed the difference if the occupants from H and L were added. This difference can also be seen in Figure 6.13, that initially only the occupants from C and E were introduced to Exit 7 initially. Similar to the prior findings for Exit 3, the flow rate was higher than the actual event.

In summary, the findings from the comparison between the simulated results in Simulex and the actual trial results are:

- Generally, Simulex produces a shorter evacuation time. Although most of the trial results have significant pre-movement times, the simulated and trial results before the 'tail' were close. These differences were within approximately half a minute.
- The flow rates were either faster or similar using Simulex. The rate increased as the number of occupants increased, except at Exit 1. This may be due to no merging of occupants from the other areas. As at Exit 2, 6 and 7 there are occupants from more than one area using those exits.
- The times of the first occupant to leave were almost the same.

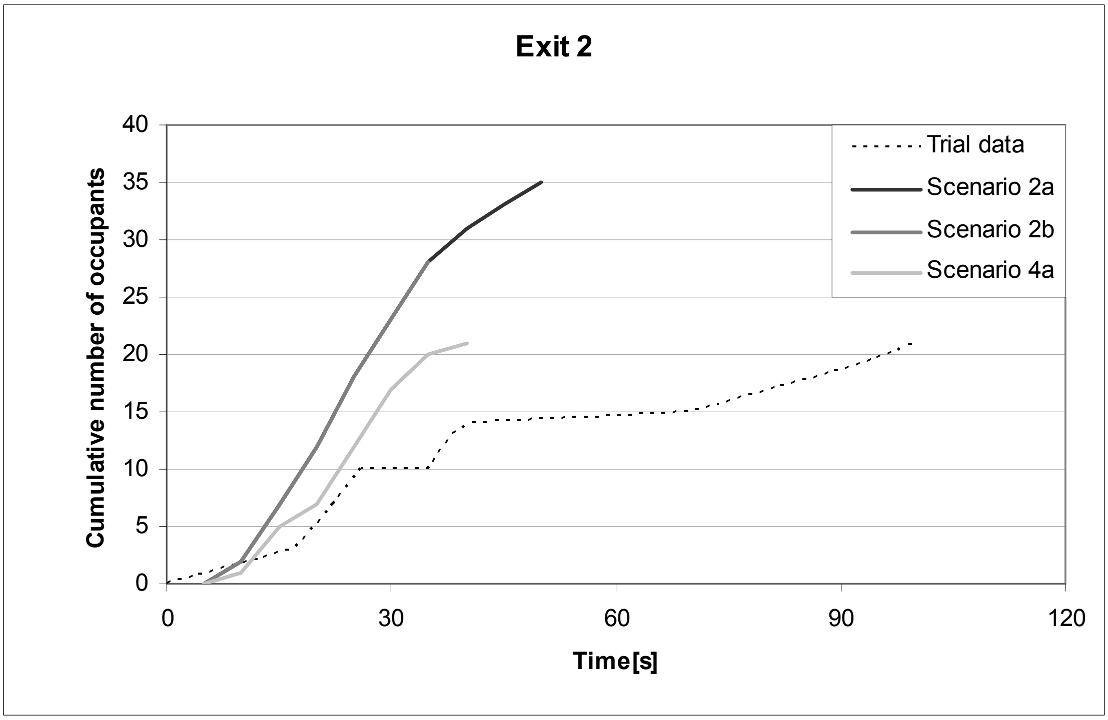


Figure 6.10: Results from Simulex for Exit 2

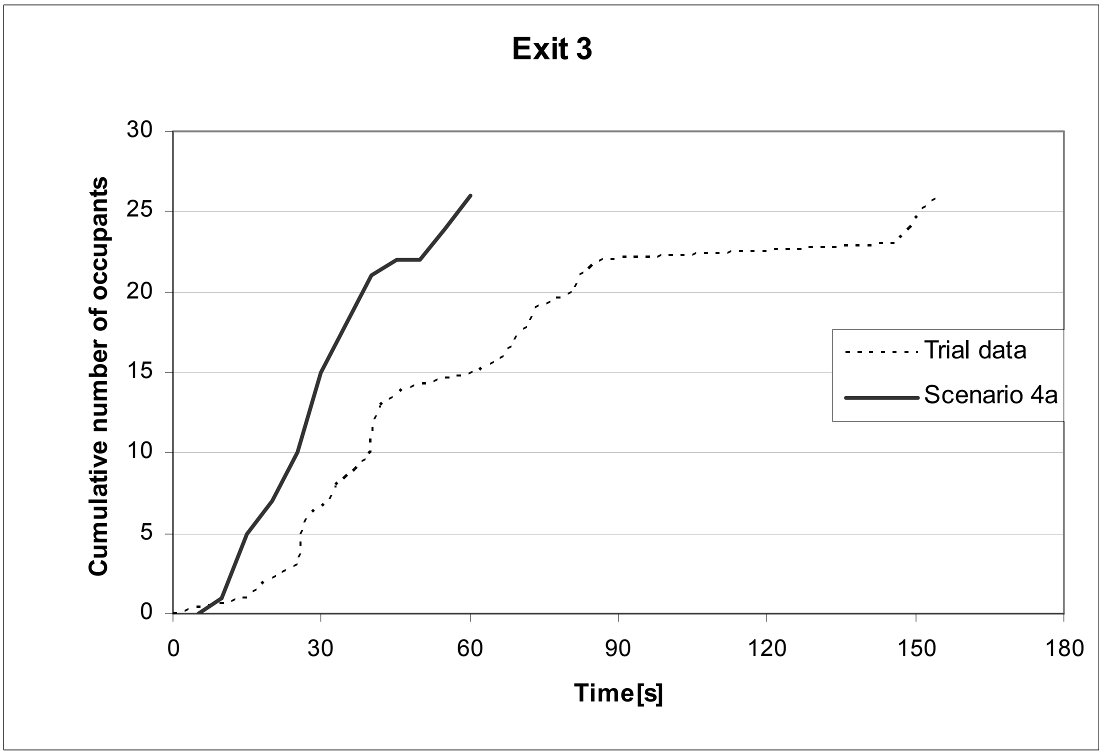


Figure 6.11: Results from Simulex for Exit 3

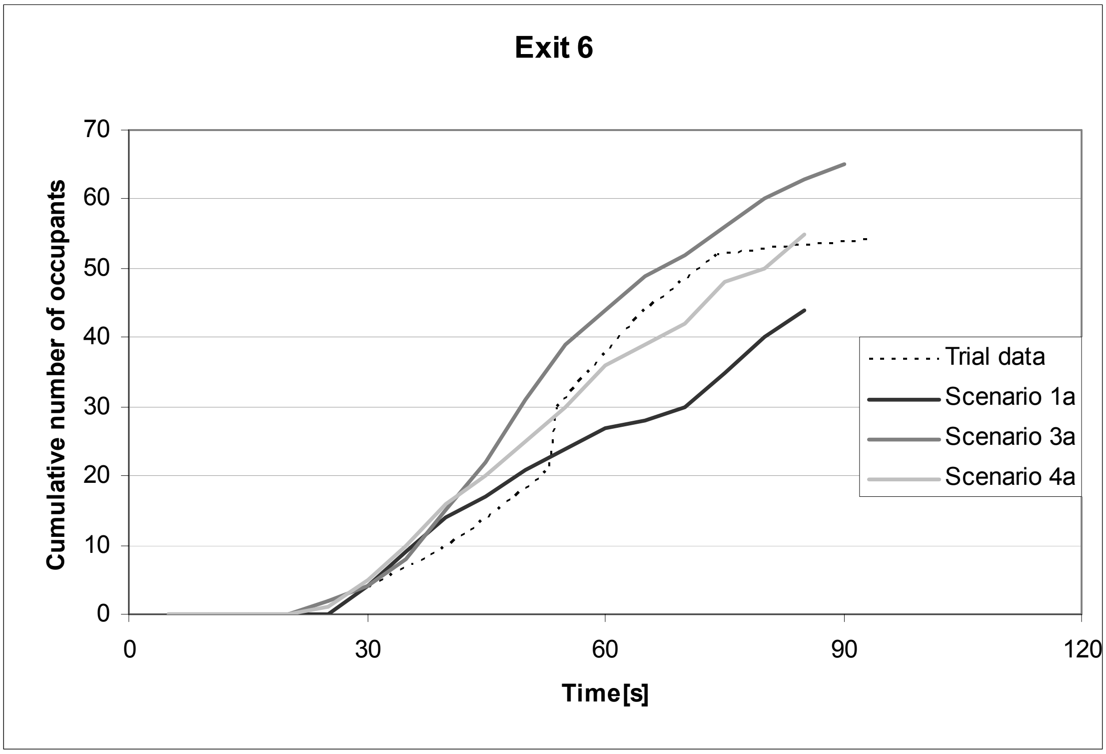


Figure 6.12: Results from Simulex for Exit 6

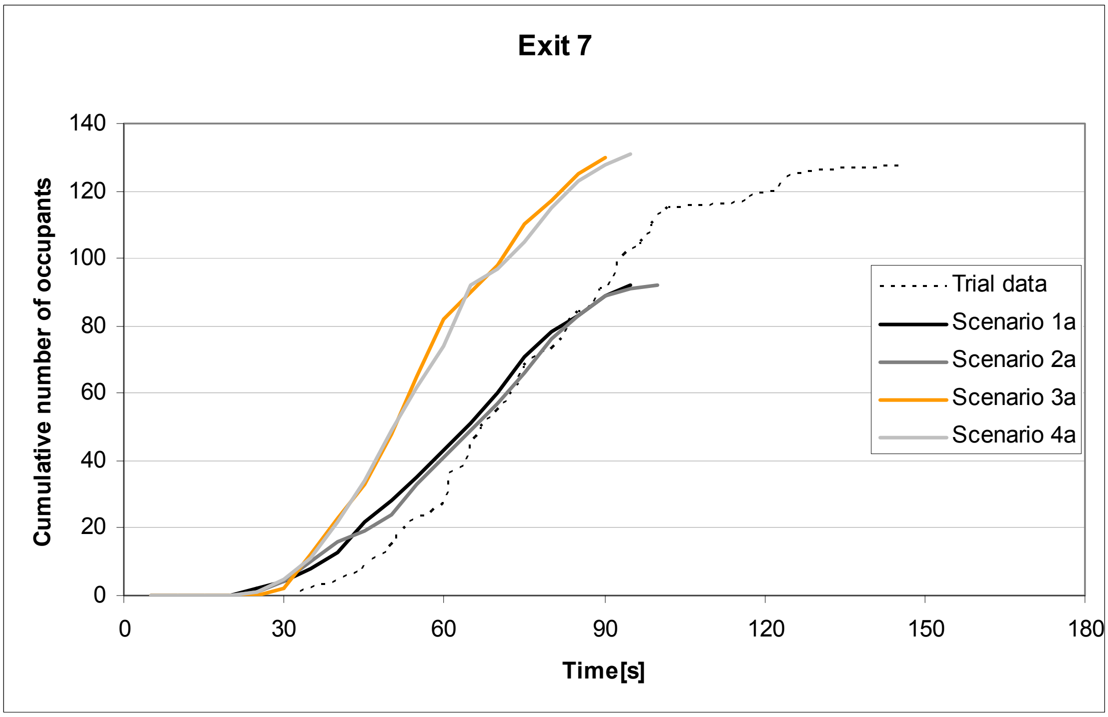


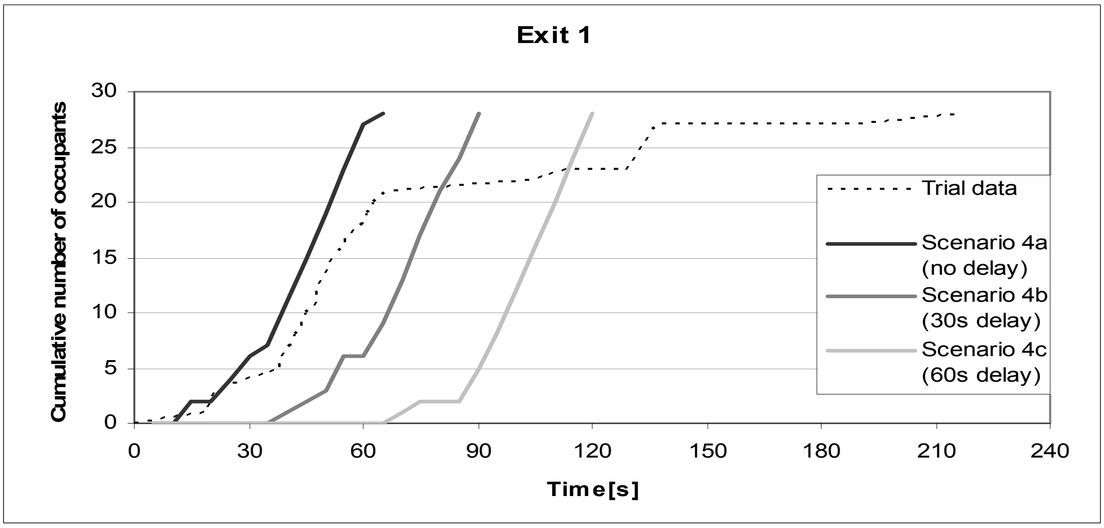
Figure 6.13: Results from Simulex for Exit 7

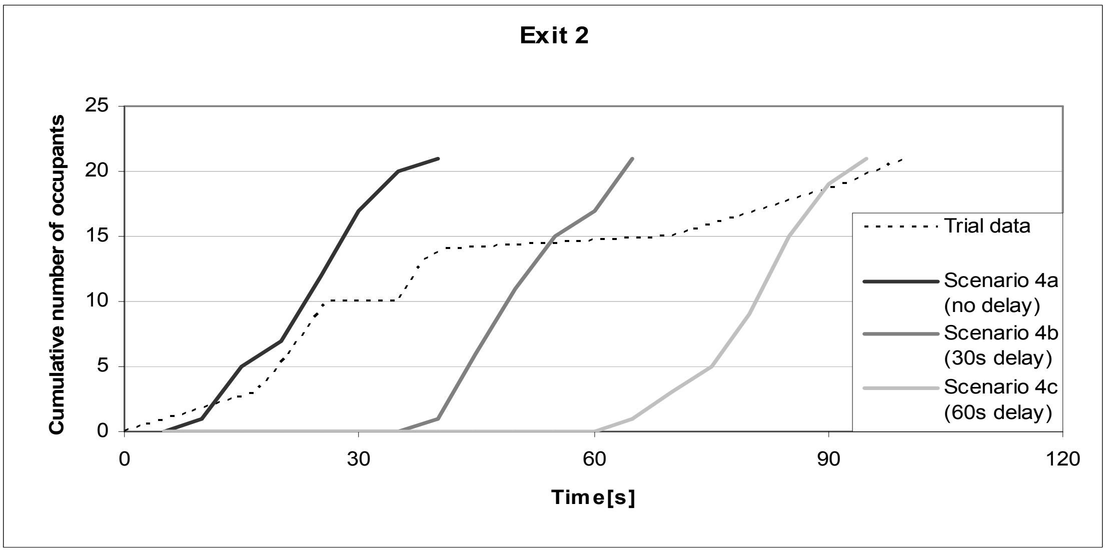
6.1.2.2 With pre-movement time

The results from Section 6.1.2.1 indicate that, only a small proportion of the occupants have a significant pre-movement time. Three scenarios were simulated in Simulex: Scenario 4a is without a pre-movement time; whereas, Scenario 4b and 4c are with an average pre-movement time of 30 seconds and 60 seconds respectively. The pre-movement times were all set to have a normal distribution with a plus/minus 10-seconds from the mean. This interval is an arbitrary number and it is assumed only for the simulations purpose.

Figure 6.14 shows the results of office building evacuations with pre-movement times. The results confirmed that the majority of the occupants have a fast response time and thus the average pre-movement times were insignificant. However, it does not exclude this time phase being a factor to cause long evacuation times at some exits. Furthermore, the results show that using normal distribution for pre-movement time is not a good approximation in these cases. A skewed distribution such as Weibull distribution (suggested by MacLennan et al., 1999) might be a more appropriate distribution.

Refer to APPENDIX B for the dimensions of the site.





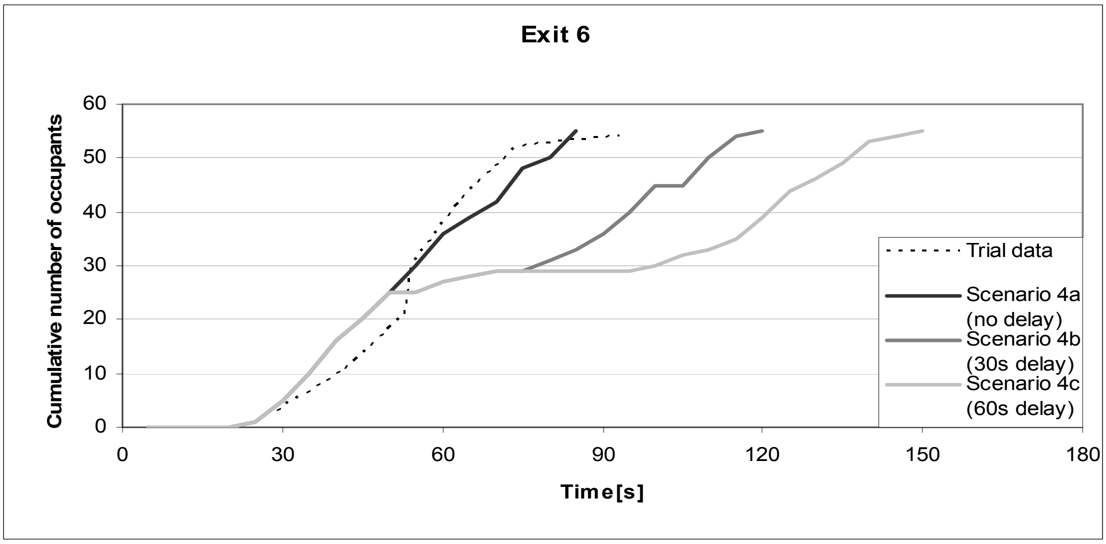


Figure 6.14: Results of PDL office building evacuations with pre-movement times.

6.2 Modelling with EvacautioNZ

6.2.1 Methodology and assumptions

This section discusses the methodology and assumptions used for the EvacuatioNZ modelling. The EvacuatioNZ modelling uses a similar methodology and assumptions to the Simulex modelling. General assumptions made for the simulations discussed in Chapter 4 were used as the inputs to the EvacuatioNZ models.

The dimensions of each room and area were based on the CAD drawings that were used in Simulex. Four different MAP files were created to model the whole site. Each MAP file modelled the areas that used the same exit. Therefore, the occupants were assumed to use the exit assigned to them. The numbers of occupants in each area were the same as in the Simulex models. The overall site evacuation was built up by four different plans in Simulex as well as in EvacuatioNZ. Four different cases of different MAP files were created. Combination of these four cases would simulate a scenario identical to Scenario 4a in the Simulex models. Thus, only one scenario for each MAP file was simulated using EvacuatioNZ.

Table 6.3: Four MAP files of PDL used in EvacuatioNZ model.

Case (MAP file)	Area modelled	Exit used
J & U	J and U	Exit 1
G & S	G & S	Exit 2
A	A	Exit 3
C & E	C, E, H, L, F	Exit 6 and Exit 7

Table 6.3 shows the four different MAP files for four different cases. Together with each of the others associated input files, these files would represent an overall evacuation at PDL. The first three MAP files are quite straightforward to construct; on the other hand, the last file is quite complicated. Refer to APPENDIX C for examples of input files.

Each MAP file is explained separately as follows:

(1) J & U

Each office room in U was model as a single node. The long corridor was divided into a series of nodes. All the occupants were only assigned to one exit behaviour type, which is the "minimum distance to safe" route.

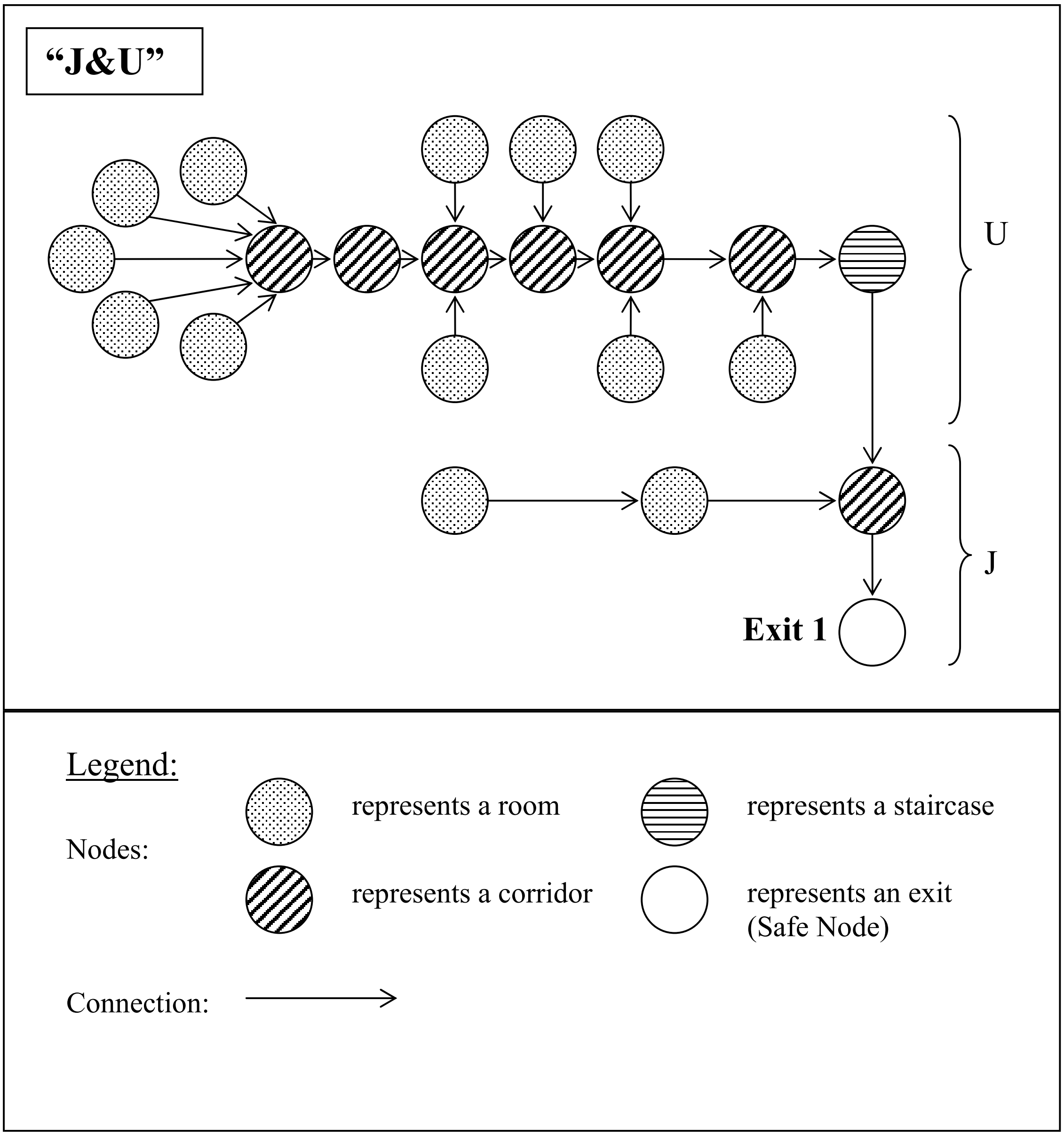


Figure 6.15: Nodal representation of "J & U" file.

(2) G & S

Similarly, each office room, as well as the open plan office area, was model as a single node. The area where the merging of occupants would occur was specified as a single node. All the occupants were only assigned to one exit behaviour type, which is the "minimum distance to safe" route.

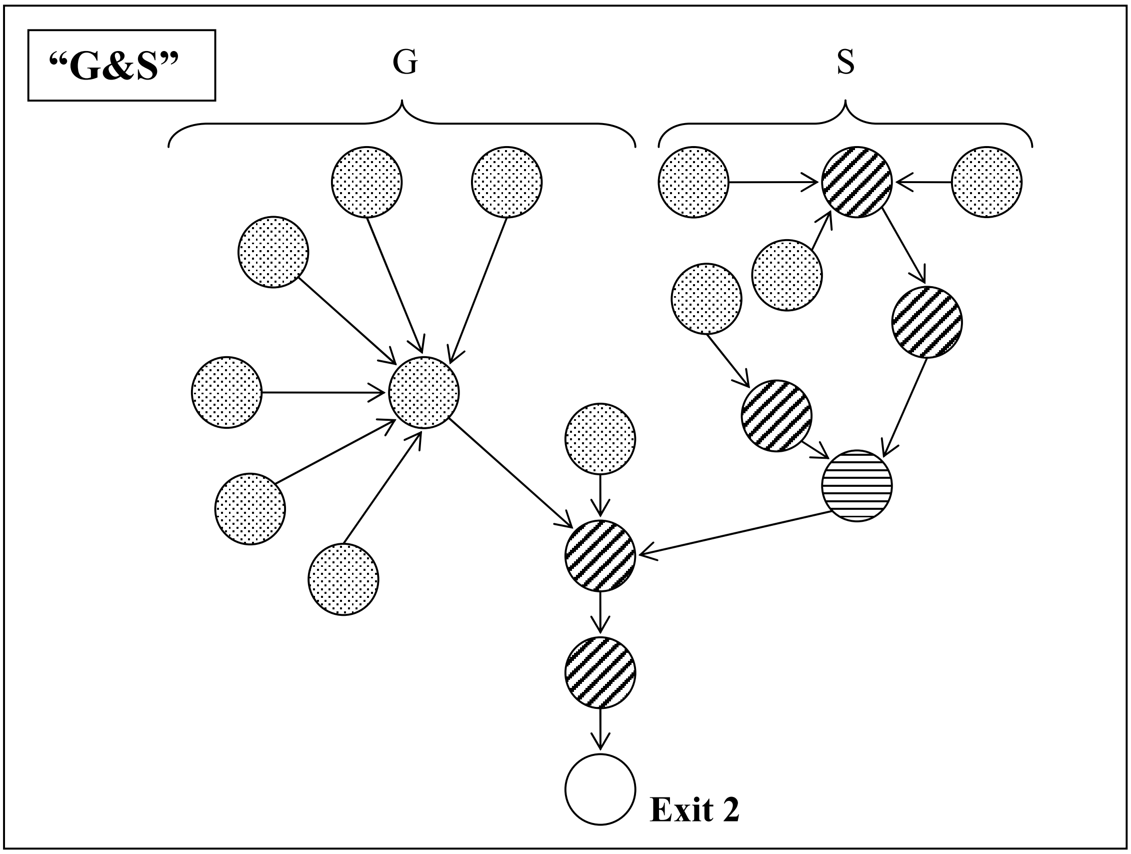


Figure 6.16: Nodal representation of "G & S" file.

(3) A

Three nodes were used to model A. Two nodes represented the two big areas, and a 'safe node' represented the exit. The "minimum distance to safe" route was specified.

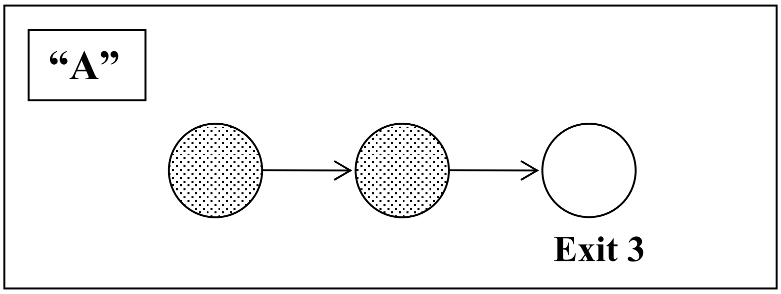


Figure 6.17: Nodal representation of "A" file.

(4) C & E

Generally, each area was represented as a single node. E was modelled into three nodes: two nodes represented two different areas that led to Exit 4 and 5 respectively and the third node represented the front of E where the customer service is located. There are two separated areas in H (see Figure 6.5) a smaller area near Exit 7 and the remaining larger area. There is a hallway between these two areas and leads to the corridor (see Chapter 5 for its definition). Therefore, both H and the hallway were modelled by two nodes. The courtyard was also modelled into several nodes where occupants from other areas merged. There would be three sources; they are from H, F and customer service. Each of these has separated path before the point where all of them merge.

As for the exit choice, the occupants in C were assigned with only one exit choice, which is the "preferred" route. This was to simulate the scenario similar to the actual evacuation and as well as to the Simulex model. The occupants in H and L were also assigned only with one exit choice, which is the "minimum nodes to safe" route. This was because the occupants in those areas could have used either one of the exits. It was found that the occupants in each area have the same number of nodes to a safe node (Exit 6 or Exit 7); therefore, by using the "minimum nodes to safe" route, it would allow in the occupants to have equal chance of using each exit.

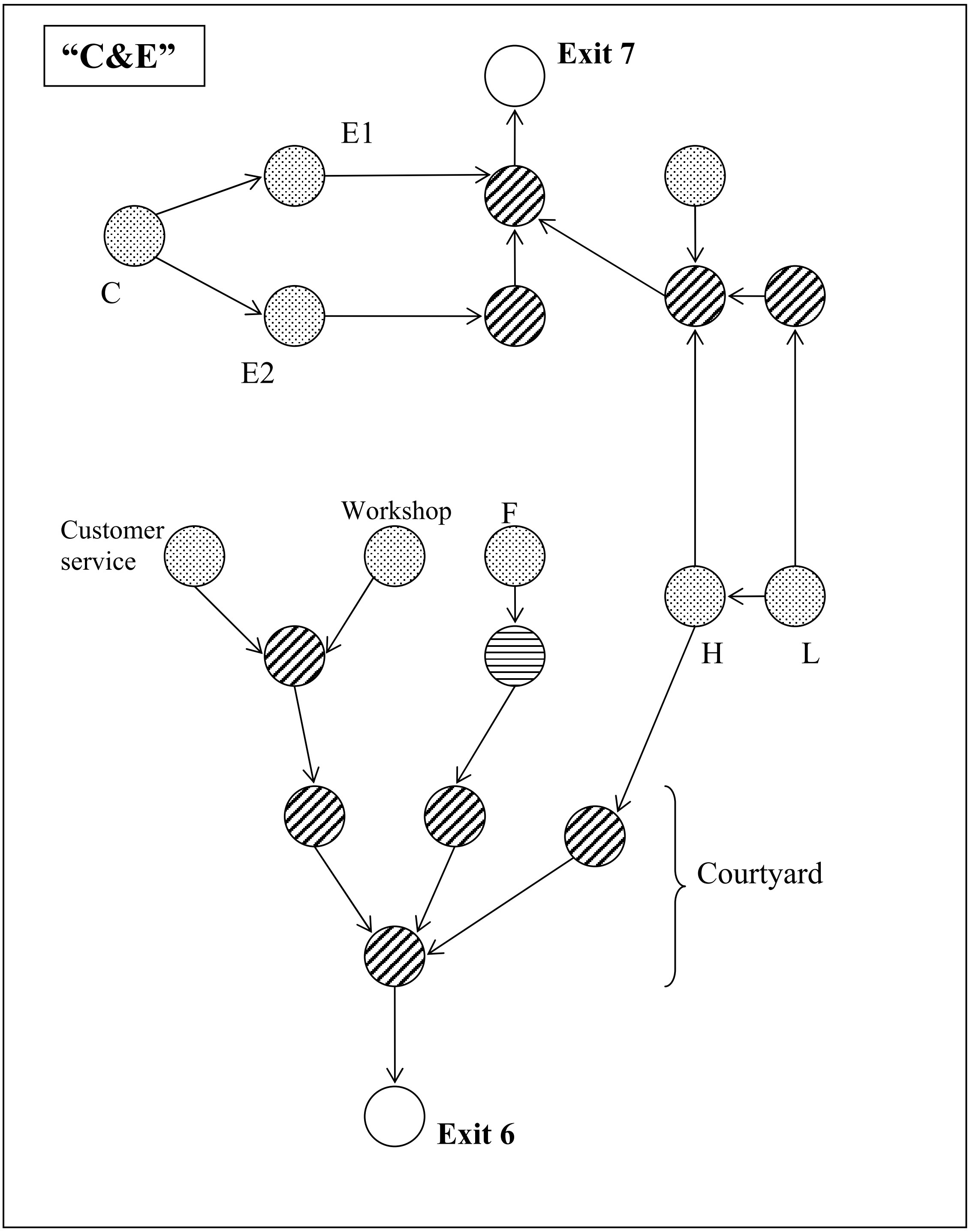


Figure 6.18: Nodal representation of "C & E" file.

Different maximum travel speeds were simulated and they are: 1.2 m/s from Nelson and MacLennan (Buchanan, 2001) and 1.7 m/s. The latter is the maximum unimpeded walking velocity for each person in Simulex. This would help to determine which speed is appropriate or close to the actual event. It should note that “random start” feature was used at all the four files.

No pre-movement time is assigned to the occupants. As discussed in the previous section, the majority of the occupants have insignificant pre-movement times, except those at Exit 1, 2 and 3. However, pre-determined pre-movement times were assigned to specific occupants that caused the ‘tail’. This is to determine if the model is able to simulate pre-movement time properly.

Before any analysis is done, it is important to determine the number of iterations that is needed to give a closest value to the converging output mean. In this case, the output mean will be the evacuation time. Three random number seeds were used to determine the convergence in this report. In EvacuatioNZ, the starting position in the random numbers table is determined by the date and time of the simulation.

Initially, a trial run of 2000 simulations was examined. The main reason is to see if the number of simulations is sufficient for the mean evacuation times to converge. As a result, it was found that 500 simulations would be sufficient. For convergence, the mean evacuation times of each run are within 1 percentage difference. The area circle in Figure 6.19 shows the percentage difference is much less than 1%, therefore 500 simulations is sufficient.

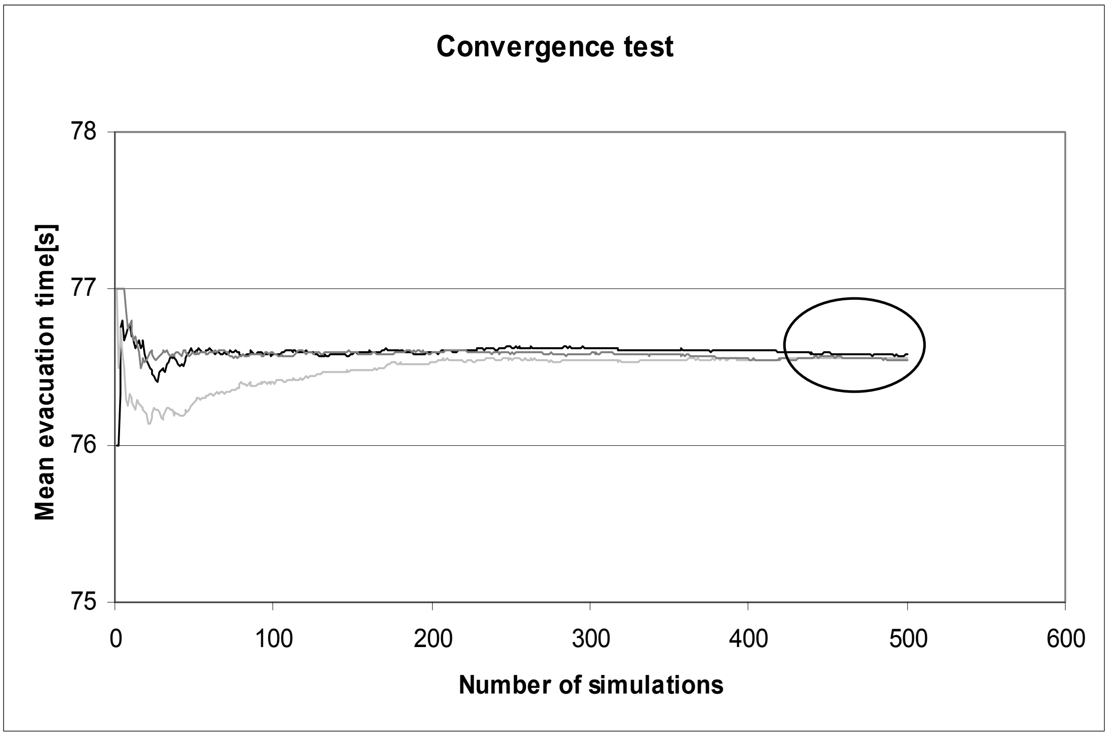


Figure 6.19: An example of convergence test.

6.2.2 Results

6.2.2.1 Without pre-movement

EvacuatioNZ produced a probabilistic evacuation times for each exit. Figure 6.20 shows a cumulative probability distribution of the evacuation time for C&E MAP file, which contains the results at Exit 6 and Exit 7. It describes that 500 repeated simulations produced a distribution for the evacuation time that ranged from around 130 seconds to 147 seconds. The recorded evacuation time at Exit 7 was 145 seconds. By comparing the simulated results and the actual time, the actual time was approximately at the 95 percentile value. Although the recorded evacuation time at Exit 6 (93 seconds) lay outside the distribution, it did not mean that the simulation results were not accurate. It should be noted that the results were the overall evacuation time when all the occupants specified in the POPULATE file were successfully in the safe nodes. Exit 1, 2 and 3 are not discussed here due to the significant pre-movement times.

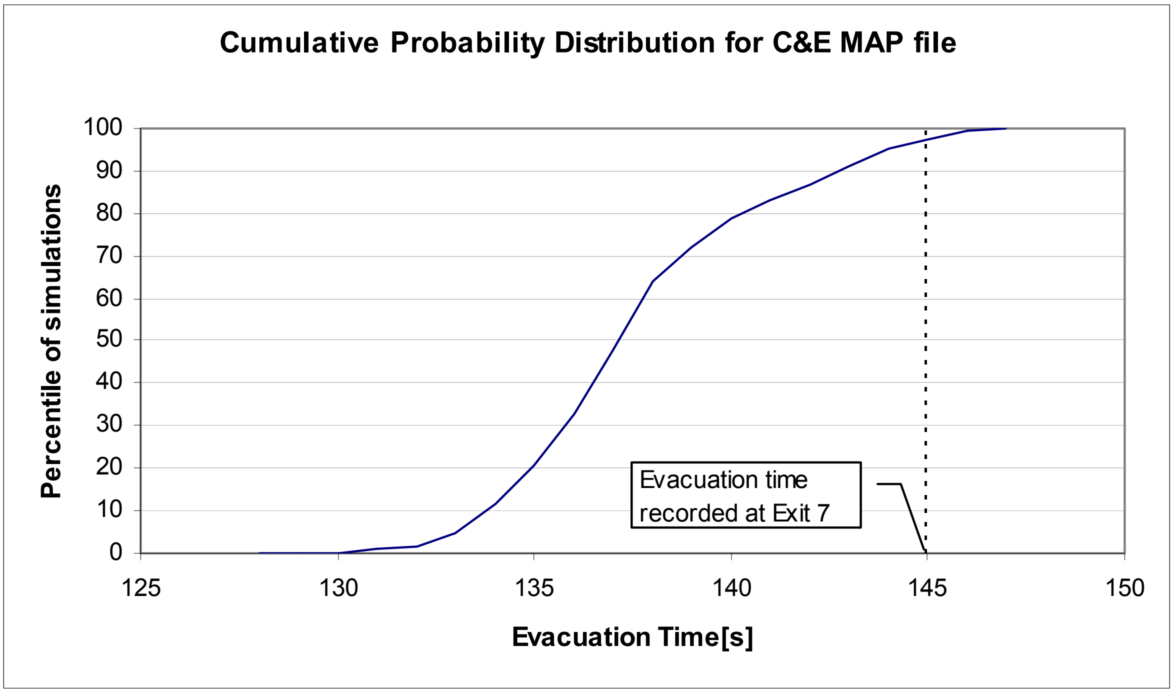


Figure 6.20: An example of EvacuatioNZ simulation results.

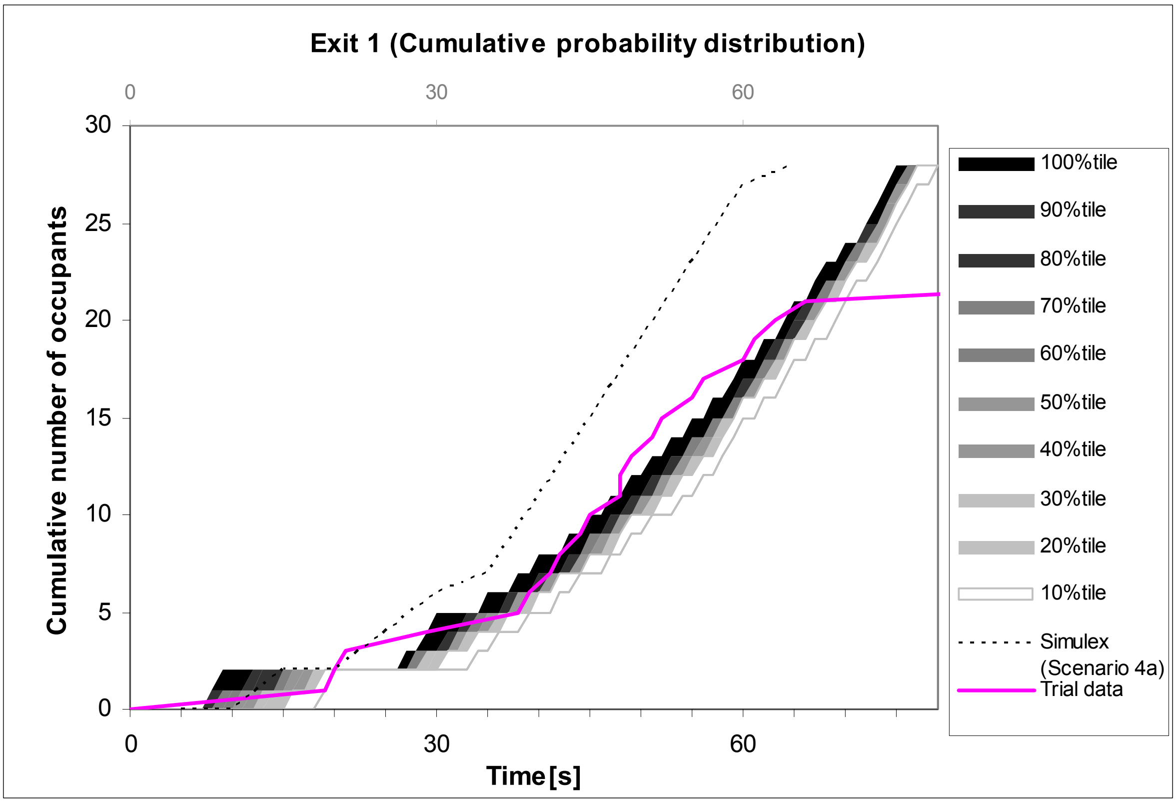


Figure 6.21: Cumulative probability distribution of the flow of occupants at Exit 1.

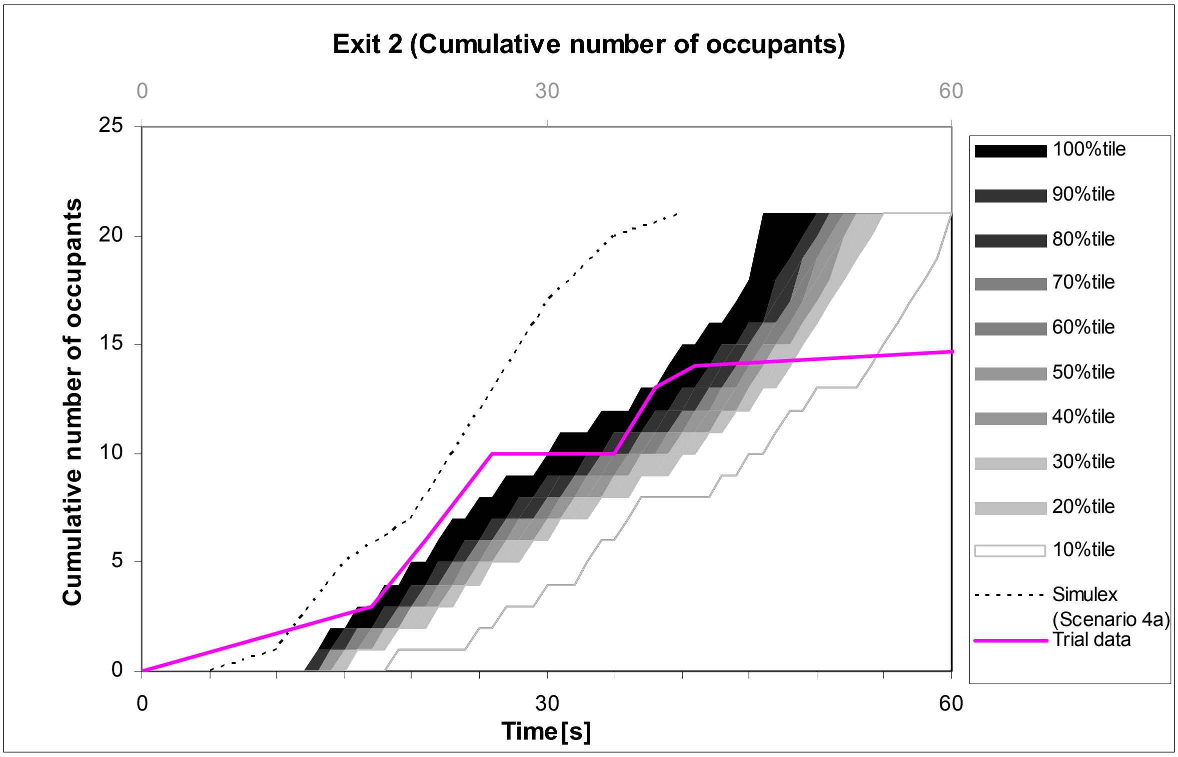


Figure 6.22: Cumulative probability distribution of the flow of occupants at Exit 2.

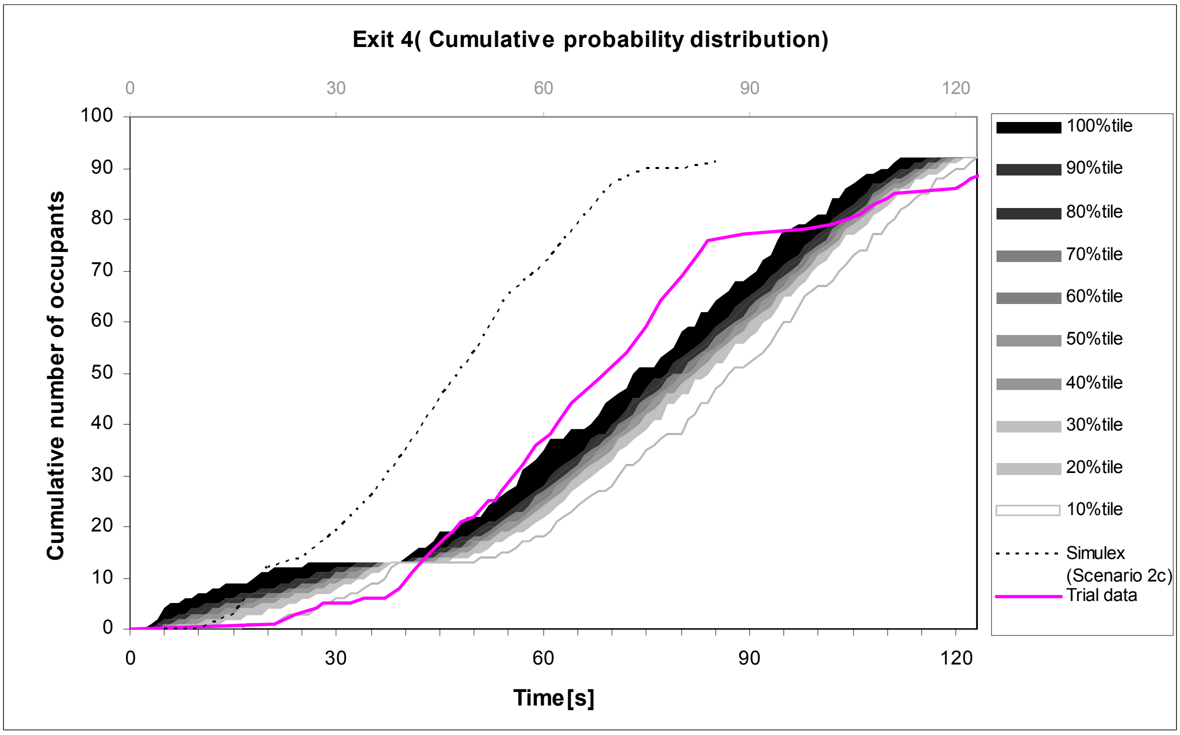


Figure 6.23: Cumulative probability distribution of the flow of occupants at Exit 4.

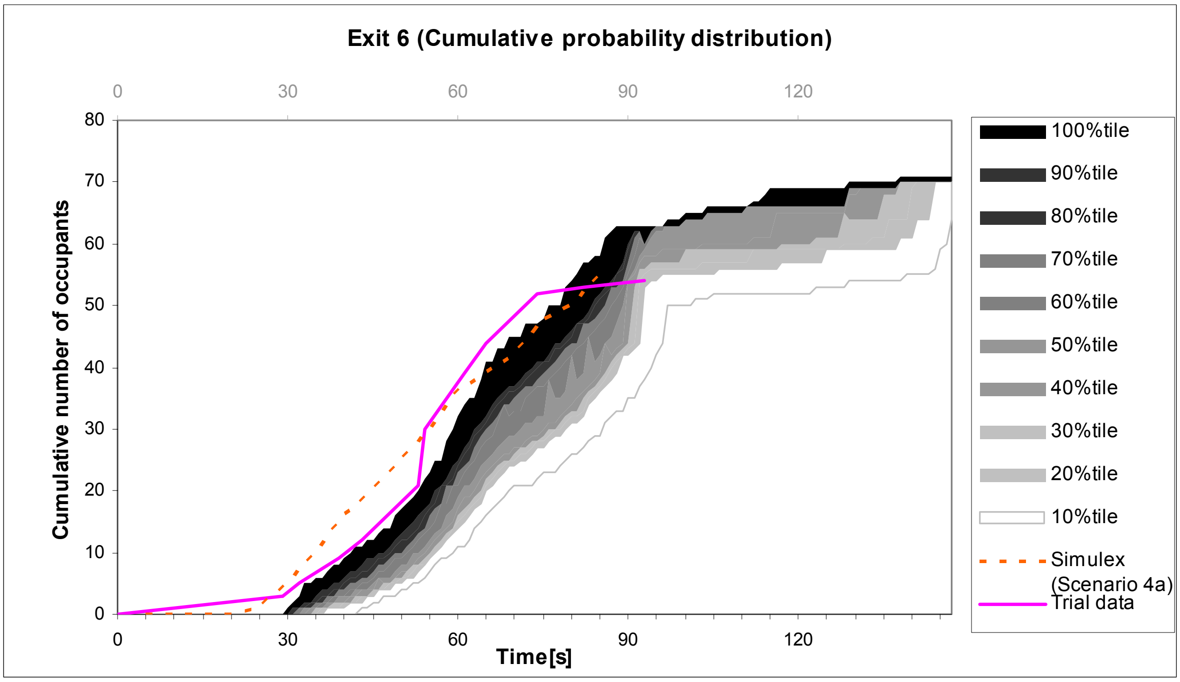


Figure 6.24: Cumulative probability distribution of the flow of occupants at Exit 6.

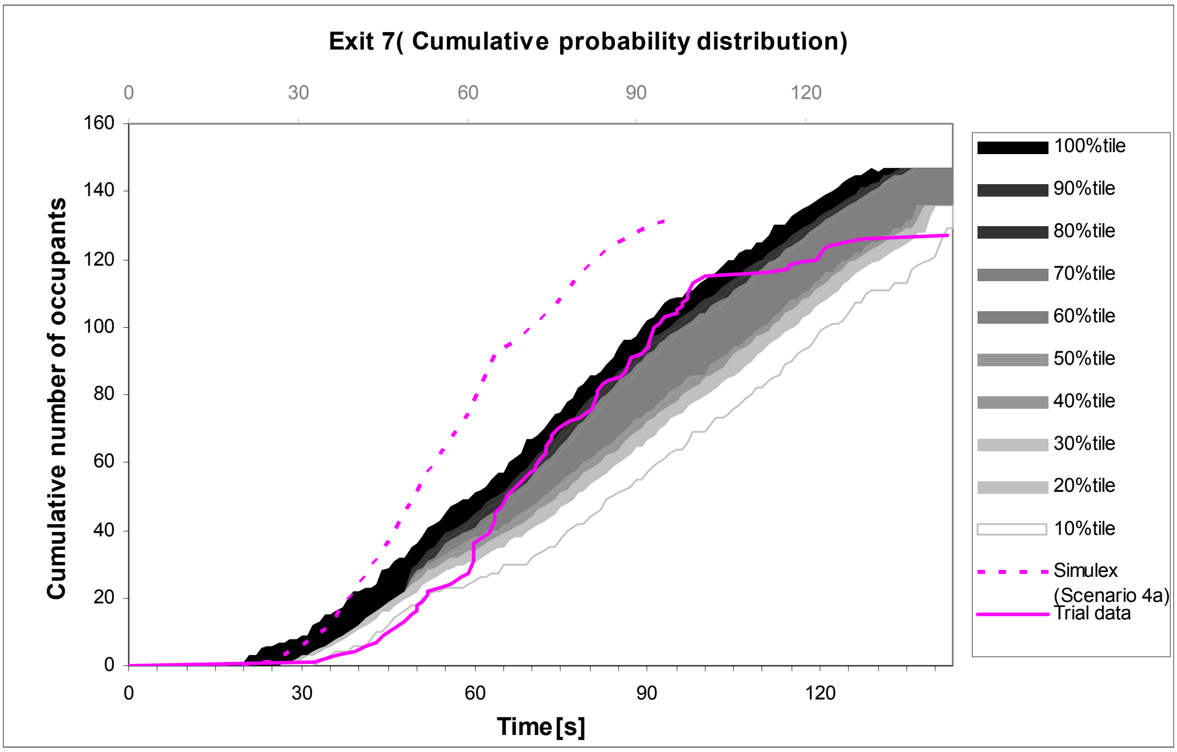


Figure 6.25: Cumulative probability distribution of the flow of occupants at Exit 7.

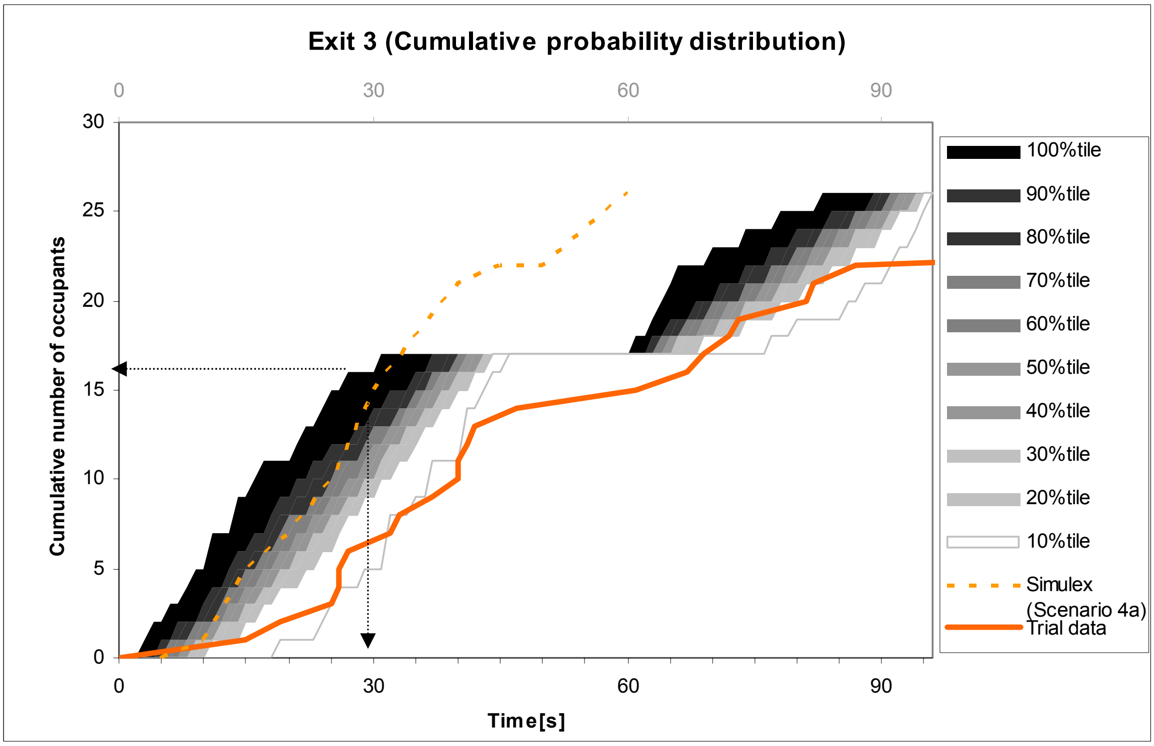


Figure 6.26: Cumulative probability distribution of the flow of occupants at Exit 3.

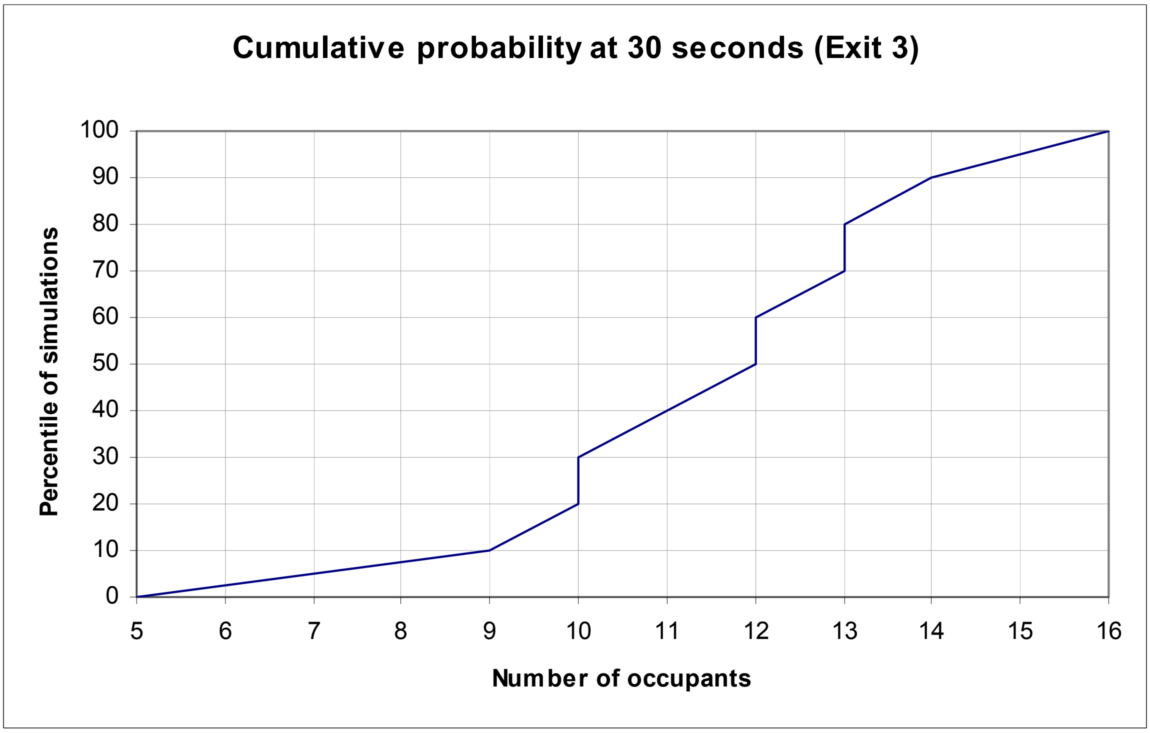


Figure 6.27: The 'cross-section' of the flow distribution (Figure 6.22) at 30 seconds.

Figure 6.21 to Figure 6.26 show what EvacuatioNZ can produce in terms of the flow of occupants through an exit. The plot describes a cumulative probability of the flow (500 simulations) at Exit 3 and compares it with the trial data. In this case, the trial data lay in the 10 percentile value most of the time. The distribution is divided into six shades, from a lighter to darker colour as the percentile increase. Figure 6.27 demonstrates the use of this cumulative probability. For example, at 30 seconds, in all 500 simulations, at least 5 occupants have left. At 50 percentile, that is 250 simulations, at least 12 people have left at 30 seconds. The maximum number of occupants that could leave in 30 seconds is 16 occupants. The slope of the curve also indicates the frequency of the number of occupants that have left. The steeper the slope, the higher the frequency.

Generally, the simulated results (flow rates) at each exit were very close to the actual evacuation, and gave a better estimation compared with Simulex. Figure 6.28 and Figure 6.29 show the flow rates for two different travel speeds at each exit. The 'range' of each speed was represented by the flow rate of the shortest evacuation time and the longest time. This provides an estimation of the distribution range.

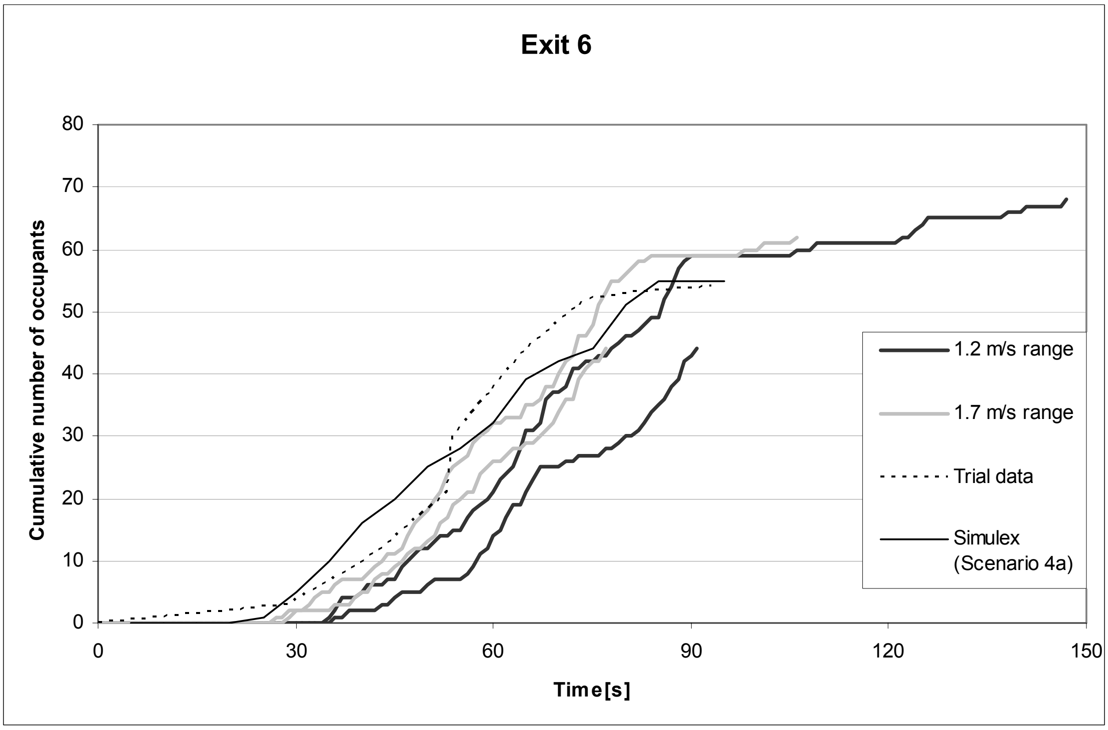
A number of findings from these two figures are:

- The maximum walking speed of 1.2 m/s showed a better result, which gave a flow rate approximated to the actual data; thus, this value would be used in all the analyses.

- Most of the flow rates gave a better approximation to the actual data compared to the Simulex results. One of the obvious results is shown in the simulations at Exit 3 (Figure 6.29). EvacuatioNZ has shown flow pattern similar to the actual flow (circled in Figure 6.29)

- The flow rate depends greatly on the geometry of the building, which is indirectly related to the queuing process. Exit 1 and Exit 2 showed that there was no significant difference in the flow rates as well as the evacuation times, but Exit 3 showed otherwise. This justifies that a queue is more likely to be formed in the office building and it is independent to the travel speed. Whereas in a large area, like A, where a long queue may not be formed, a faster walking speed gave a higher flow rate and consequently a quicker evacuation time. However, if the number of occupants is higher, the results may be different.

- The occupants in H and L did choose which exit to use as expected (see Figure 6.28). This is shown in Figure 6.28 that the total number of occupants in each simulations at each exit were different. Also, by analysing the output files, especially the NODES files, the "preferred" exit behaviour type is working satisfactorily as specified.



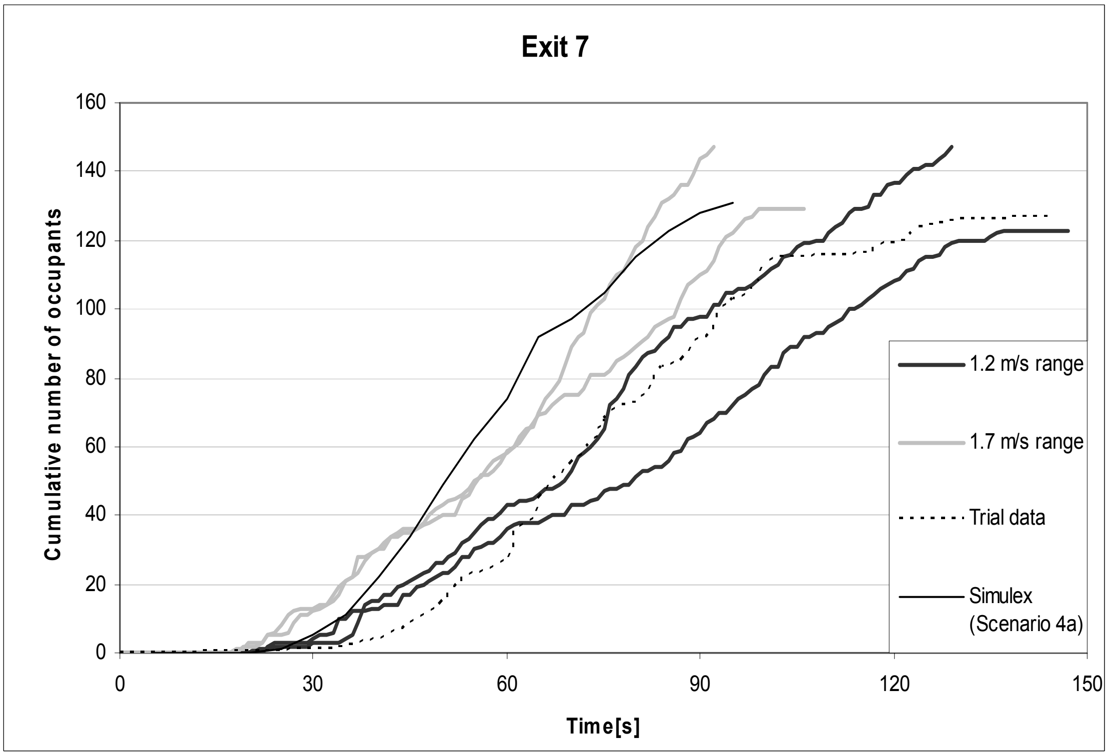


Figure 6.28: Comparison of flow rates at Exit 6 and Exit 7.

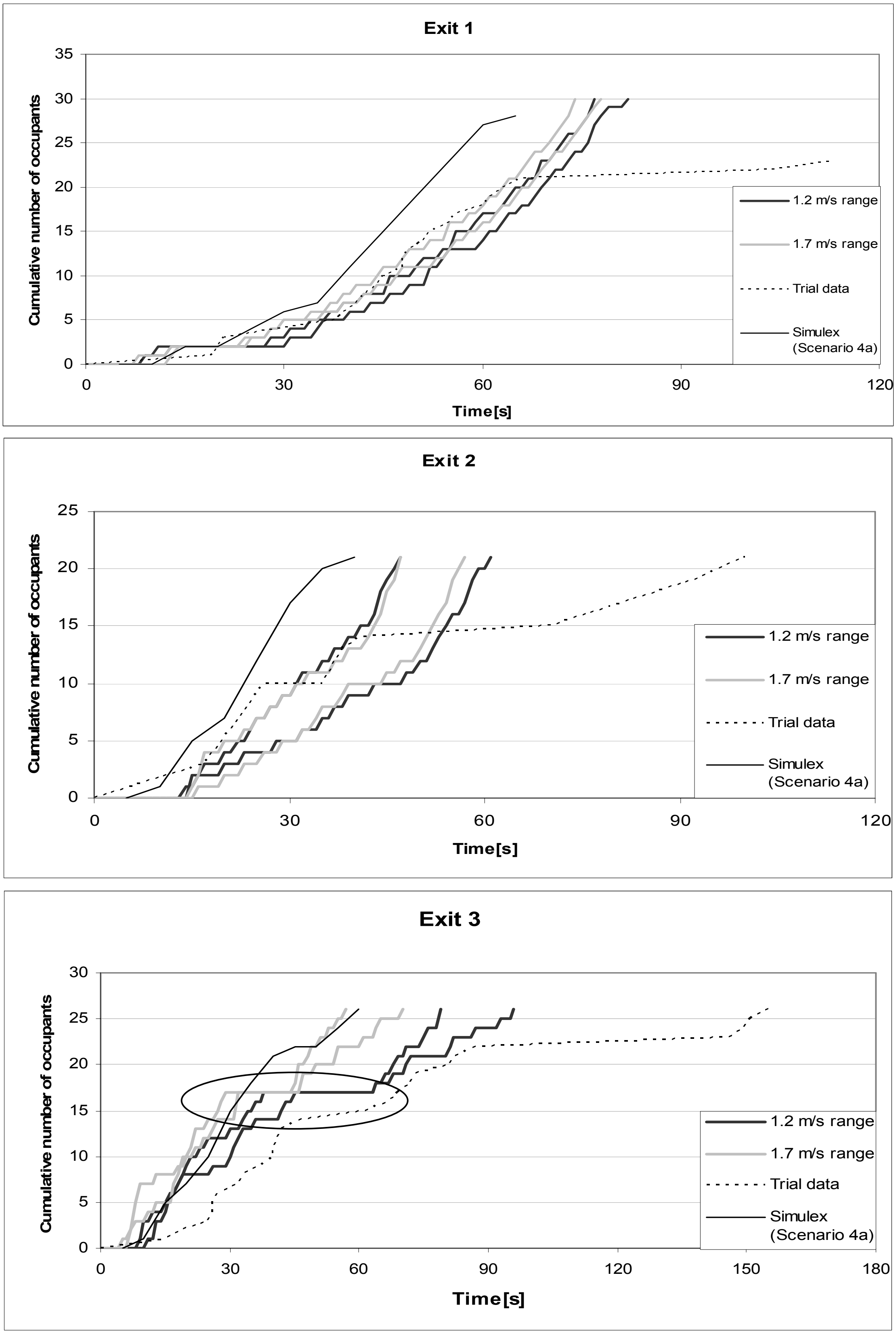


Figure 6.29: Comparison of flow rates at Exit 1, 2 and 3.

6.2.2.2 With pre-movement

The pre-movement times assigned in the simulation models were pre-determined according to the actual data at each exit (see Figure 5.2). The exits under discussion are Exit 1, 2 and 3. These are the exits where significant pre-movement times occurred.

Each exit had a different pre-movement time. For Exit 1, there were two distinct pre-movement times, when the wardens appeared (about 120 seconds) and later when a couple of occupants left (about 200 seconds). Therefore, by taking into account of the travel time, which was assumed as the time between when the alarm sounded and when the first occupant left (about 20 seconds), the pre-movement time used were 100 seconds and 180 seconds respectively. Similarly, for Exit 2 and 3, the pre-movement times were 80 seconds and 60 seconds respectively. The pre-movement time for Exit 3 was assigned to the occupants in both rooms. It is noted that these times were only specified to a small proportion of the occupants (about 2 to 5 occupants).

The results indicated that the recorded evacuation times lay in all the distributions as shown in Figure 6.30. The trial data lay above the 50 percentile at Exit 1 and Exit 3, whereas at Exit 2 it nearly fell outside the range. The flows of the occupants at these exits were very close to the actual flow (Figure 6.31).

It must be noted that this method of assigning of a pre-movement time is not recommended as a general design method because designers and fire engineers would not know what the pre-movement time for their buildings would be at the beginning. It was used in the report to demonstrate the accuracy of the EvacuatioNZ results.

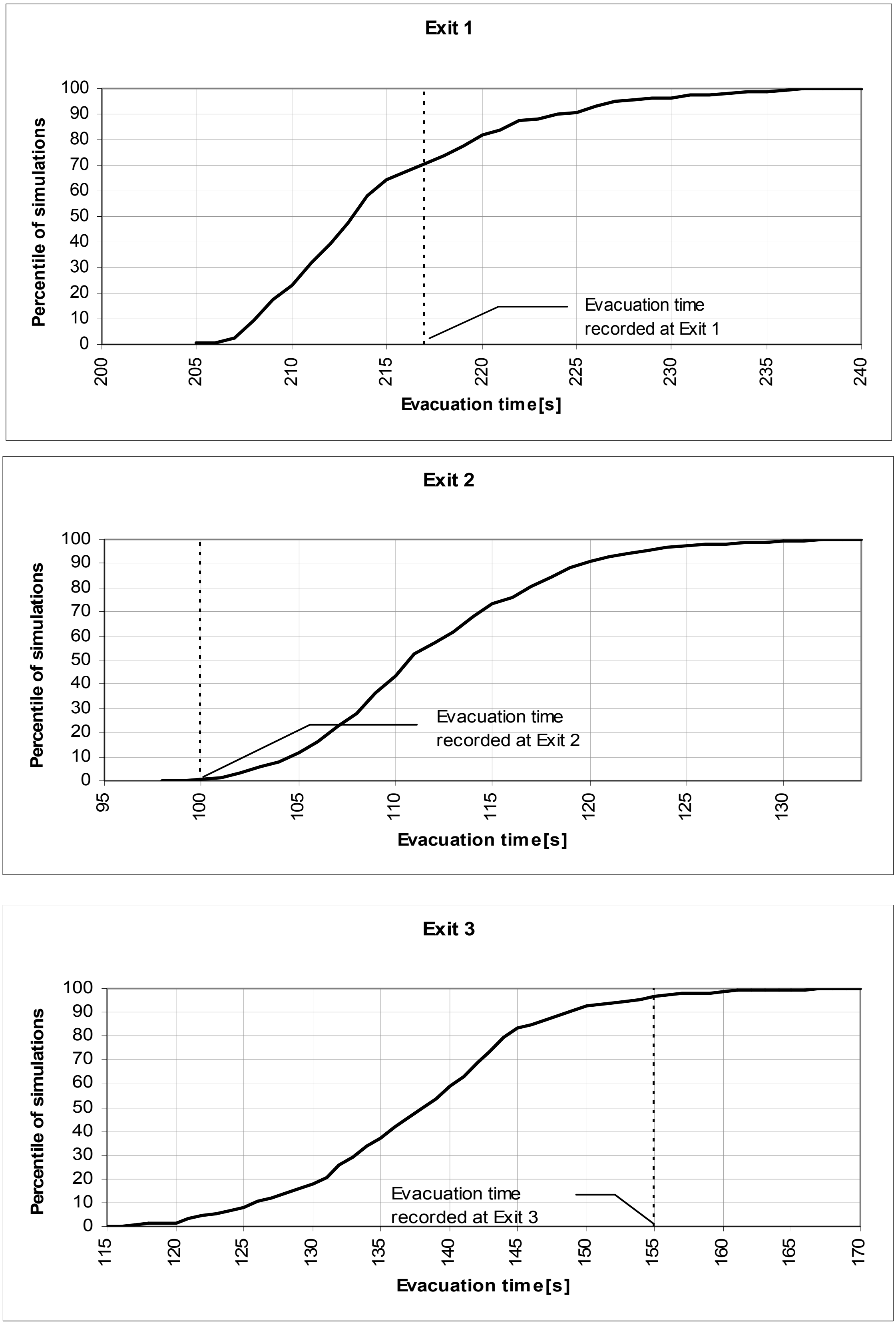
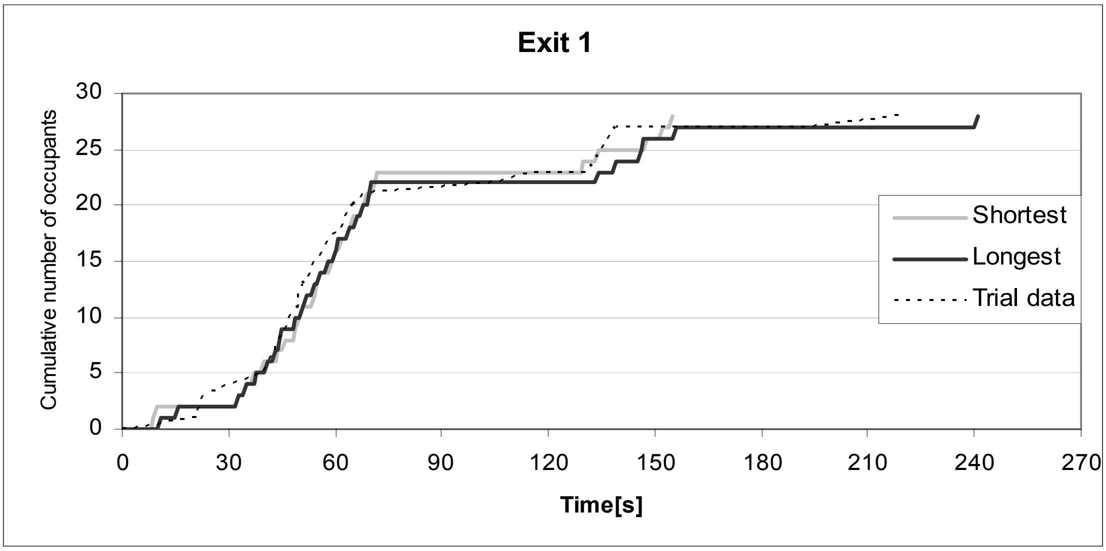
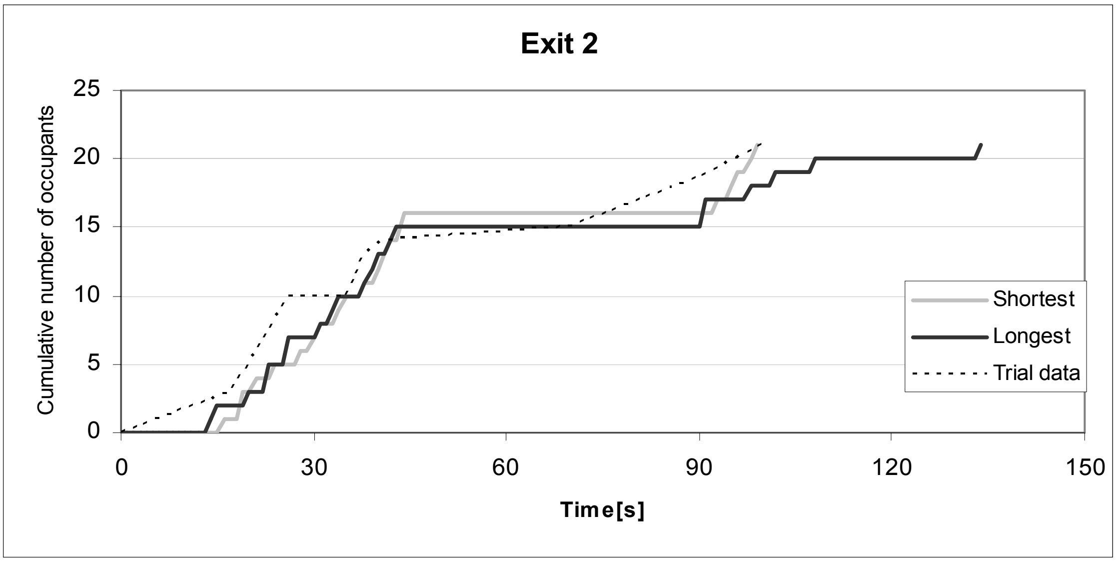


Figure 6.30: EvacuatioNZ results (Cumulative probability distribution) with pre-movement time for Exit 1, 2 and 3.





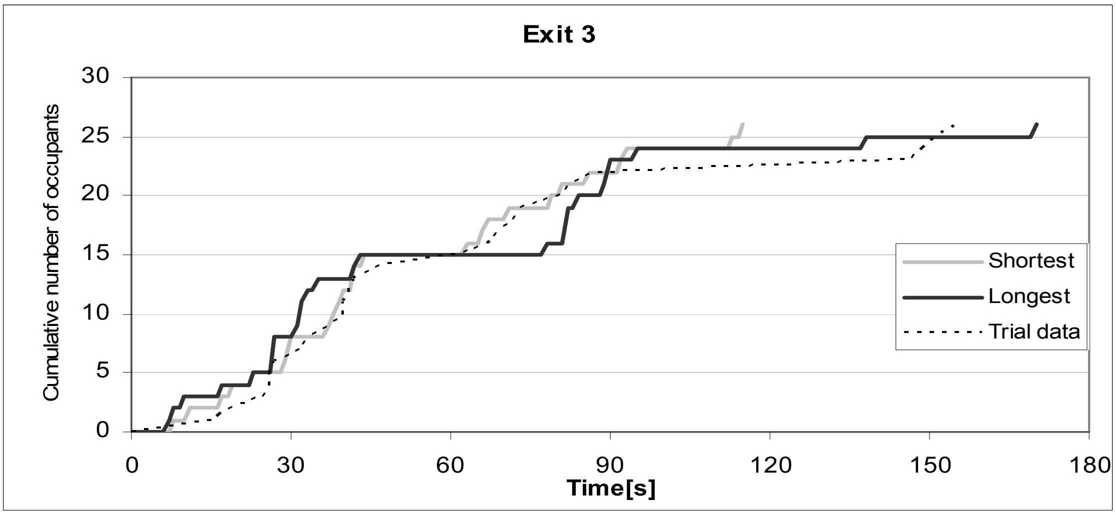


Figure 6.31: Comparison of flow of occupants in EvacuatioNZ (with pre-movement times) and trial data for Exit 1, 2 and 3

7. Analysis on a lecture theatre evacuation

This chapter discusses the results of simulation a lecture theatre evacuation using Simulex and EvacuatioNZ. The trial evacuation is extracted from Kimura and Sime (1989) and Sime (1992). Their study focused on the exit choice behaviour during the evacuation of the two lecture theatres. They also looked at the distance, direction and time taken to leave a setting in which there is an entrance and emergency fire exit. The two lecture theatres in their study, the front (F) theatre and the rear (R) theatre, both have an entrance and an emergency fire exit. The front lecture theatre has both exits at the back; the rear theatre has an entrance at a rear corner and fire exit at a front corner. Despite the exit locations, the two lecture theatres have the same room dimensions and seating arrangement.

The width of the theatre is 8.56m and the length is 10.47m. The entrance is 0.8m wide and the fire door is 0.76m wide. This emergency exit has a “Fire Exit” sign and a push bar that can only open from the inside, and it leads to directly to the outside. The theatre floor has a gradually sloping incline from the back to the front of it. However, only the front lecture theatre evacuation was used in this report.

In their study, the evacuation was unannounced, and none of the students had been in an evacuation of the building before. The method of recording the evacuees through an exit is similar to the exercise discussed in Chapter 5. Instead of using data loggers, this research appears to have used audio tape recorders. In addition, each evacuee was required to fill out a short questionnaire that included a plan of the lecture theatre on which he or she would indicate the seating position and the path to an exit.

The results of this evacuation showed that of the 56 people in the lecture theatre at the time of the alarm, 31 people used the entrance and 25 people used the fire exit (Figure 7.1). Although only 49 people returned the questionnaire, it was sufficient to give a high response rate (Note that only 45 of them had marked their seating locations as shown in Figure 7.1). It was found that 88% of that 49 people had left within two and a half minutes (Table 7.1). The first and the last person left were at 47 seconds and 3 minutes and 1 second respectively. It was also noted that people were more likely to leave by the nearest exit (approximately 75% of the evacuees). People who left before one and a half minutes seated near the entrance, whereas no one used the fire exit until one and a half minutes after the alarm sounded. The reasons for those who used the fire exit were not only because they seated near the exit, but also because the entrance was already being fully used, thus they used the fire exit as an alternative to the entrance.

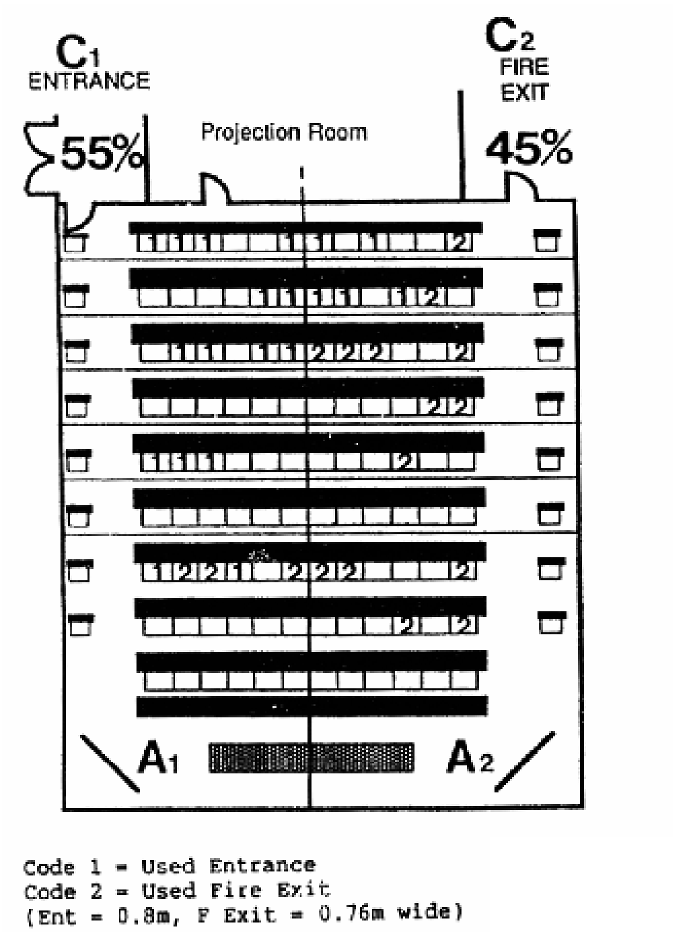


Figure 7.1: Front lecture theatre (Study 1). (Reproduced from Sime, 1992)

Table 7.1: Number of people leaving the Front lecture theatre within different half minute intervals from the alarm bell sounding (N=49, from Study 1). (Modified from Kimura and Sime, 1989)

	1 min	1 min 30	2 min	2 min 30	2 min 30+
Fire Exit	0	0	9	10	5
Entrance	4	13	7	0	1
Total cumulative frequency	**4**	**17**	**33**	**43**	**49**
Total cumulative %	**8**	**35**	**68**	**88**	**100**

It was observed that the lecturer did not immediately react to the fire alarm. Although he acknowledged the alarm, he continued his lecture. It was not until 13 seconds after the start of the alarm he muttered, "We'd better all run for the exits". He even talked to a student on the front row after that.

A follow-up evacuation study was done one year later with a different group of students, which was named as Study 2. In Study 2, the lecturer was informed beforehand of the alarm and was instructed to ask students to leave. In both studies, the students were not told which exit to use. Of 63 people in the theatre, 63% used the entrance and 38% used the fire exit. These results were quite consistent with those of Study 1. However, Study 2 showed a faster response and a shorter evacuation time. This indicates that an instruction from an authoritative source is an important influence on exit behaviour (evacuation time of 3 minutes in Study 1 as oppose to 1 ½ minutes in Study 2). The results of both studies were shown in Table 7.2.

Table 7.2: Range of times (mins:secs) to leave by the Entrance and the Fire Exit in the Front lecture theatre N= Number of people. (Modified from Sime , 1992)

F theatre	Entrance First	Entrance Last	Time span	N	Fire Exit First	Fire Exit Last	Time span	N
Study 1	0:47	2:54	2:07	31 (55%)	1:35	3:01	1:26	25 (45%)
Study 2	0:17	1:28	1:11	39 (62%)	0:21	1:15	0:54	24 (38%)

Sime (1992) stated that in the front lecture theatre, the average “time to start”, which is from the onset of the alarm to starting to move, and average “time to move”, which is the time spent in actually moving the travel distance from a seat to an exit, were 31.7 seconds and 13.9 seconds respectively. This gave a total time (average) of 45.6 seconds.

All the relevant materials to this chapter are included in APPENDIX D.

7.1 Modelling with Simulex

7.1.1 Methodology and assumptions

A plan was drawn similar to Figure 7.1 using a CAD program. The theatre dimensions and the width of two exit doors were given, but the assembly setting in the theatre had to be measured from the diagram using the provided scale. It is noted that Figure 7.1 is not to scale. It was estimated that each row is 6m long and 0.6m wide. The latter dimension was measured between the shaded rows. Figure 7.2 shows the setting modelled in Simulex. Refer to APPENDIX D for the diagrams of each individual exit choice in relation to the seating location for both studies.

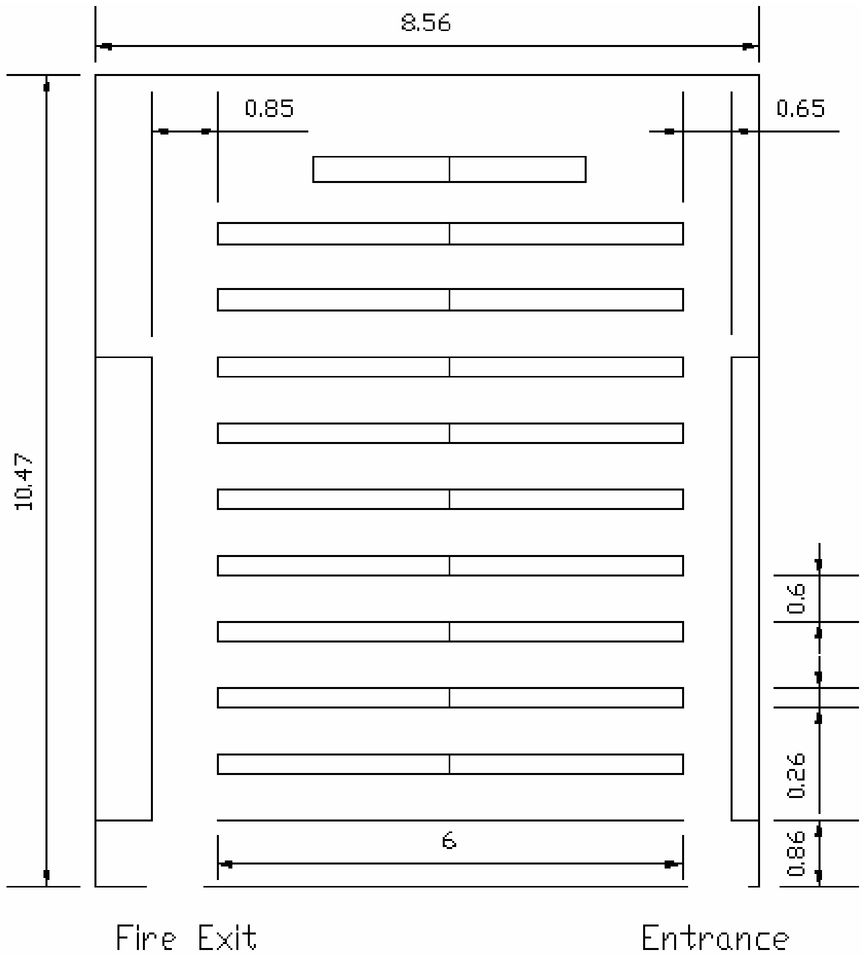


Figure 7.2: Theatre setting modelled in Simulex.

There is no information on the seating condition in the theatre. The seats could be either fixed or flipped. The seating condition could influence the flow and the evacuation time. However, it is assumed that the seat can be flipped to create more space. The reason for only considering flipped condition is because the area in a row was just enough to have around ten to eleven (with difficulty) people in Simulex model. If the seats were fixed, then it was not possible to have the required number of people in each row. Also, the theatre is modelled as a flat surface. It is assumed that its gradually sloping incline would not have a significant effect on the occupants' movement.

Five scenarios have been simulated with the data available from Study 1 and 2 as the inputs. In all these scenarios, the students were characterised as "office staff" in the model, which comprises 30% females, 40% males and 30% average body types. The students were assumed to choose the shortest route to the nearest exits, which is why the default distance map was used. From Study 2, it seemed that the lecturer was not included in the total number of people nor marked in the diagram together with the students.

Table 7.3: Summary of the scenarios simulated for the lecture theatre in Simulex.

	Total number of occupants	**Response time**		
		Distribution	**Mean Time (second)**	**Occupants applicable**
Scenario 1	56 (Study 1)	Random	1	All
Scenario 2	56 (Study 1)	Normal	30	All
Scenario 3	56 (Study 1)	Normal	45; 90	Those used the Entrance; those used the Fire exit
Scenario 4	63 (Study 2)	Random	1	All
Scenario 5	63 (Study 2)	Normal	30	All

Table 7.3 shows the scenarios that were simulated in Simulex. Scenario 1, 2 and 3 have the same number of occupants as in Study 1. Occupants were added to each row correspond to the information given in Study 1 (Figure 7.1). Those missing number of occupants were assumed to be randomly added to any rows to make up a total of 56 occupants. Scenario 4 and Scenario 5 had the same number of occupants and occupant location as in Study 2. In Scenario 1 and 3, all the occupants did not have a response time; whereas in Scenario 2 and 4, a pre-movement time of 30 seconds was added to all the occupants. This pre-movement time was assumed accordingly to the time mentioned previously. In Scenario 3, occupants who were closer to the entrance were assigned with a pre-movement time of 45 seconds and to the fire exit 90 seconds. Basically the lecture theatre was divided into half from the middle of each row and the occupants in the half near the entrance would leave by the entrance, otherwise the fire exit. These pre-movement times were assumed accordingly to Study 1 and were based on the time the first occupant left each exit (Table 7.2).

Scenario 5 was expected to produce a close result to Study 2. The average 30-second pre-movement time was assumed. It is noted that all the pre-movement times were assumed to be normally distributed. The study by Olsson and Regan (1998) found that the average pre-movement time for the two lecture theatres (with a siren alarm system) was 33 seconds.

It is noted that Table 7.1 does not have a complete flow of people (only 49 out of 56 people). Therefore, an assumption has been made so that these numbers were added to the intervals near the end of the evacuation (Table 7.4). This is the data used as the comparison in the later simulations.

Table 7.4: The assumed flow rate of people in Study 1 (modified from Table 7.1)

	1 min	1 min 30	2 min	2 min 30	2 min 30+
Fire Exit	0	0	9	10	6
Entrance	4	13	7	4	3
Total cumulative frequency	**4**	**17**	**33**	**47**	**56**

7.1.2 Results

All the simulations worked fine; no one was stuck at any point. Simulex displays a good visual simulation of the evacuation, which enables the user to identify any problem areas such as bottleneck areas. Figure 7.3 shows the typical illustrations of those scenarios. The occupants were divided into two halves from the middle of each row; each half went to the closest exit. During the simulated evacuations, the movement of the occupants showed a good representation of how people would move in real life. For example, people in a row would wait until they have the chance to enter an aisle. This could be due to either the aisle was not full or the people in the aisle gave way to them.

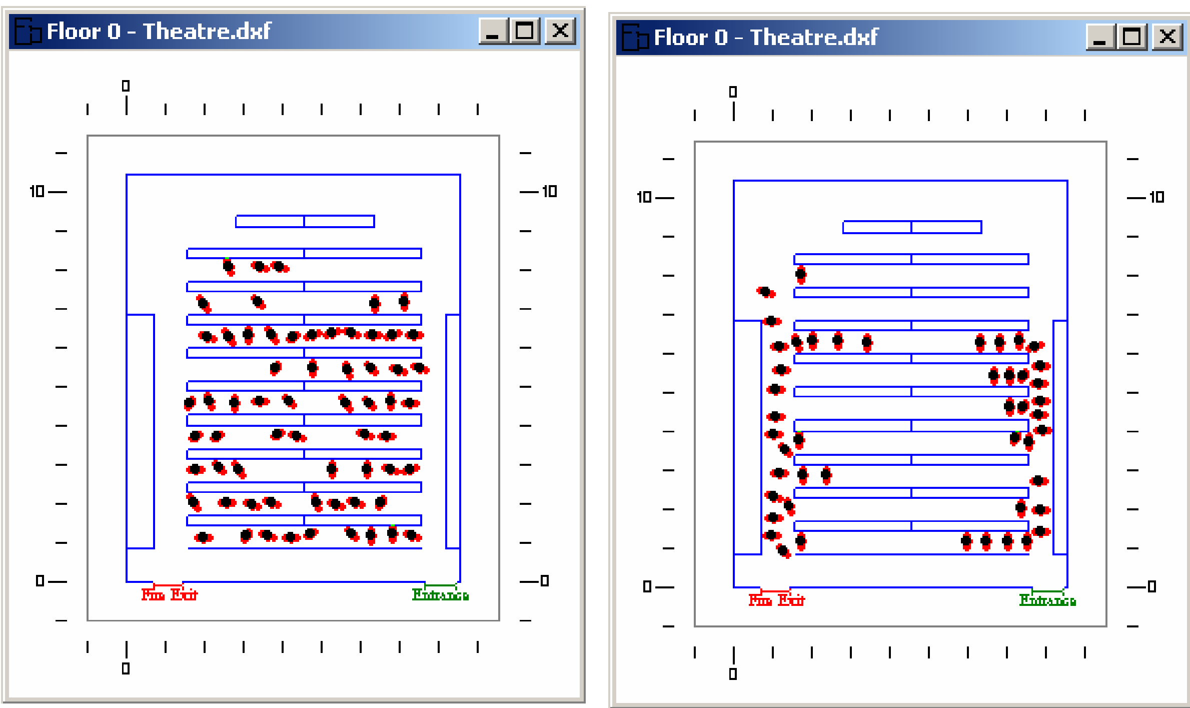


Figure 7.3: Illustrations of the lecture theatre (Scenario 4), at the beginning (left) and during the evacuation (right)

By using the default distance map, the occupants used the shortest route to the nearest exit. As a result, the number of occupants at each exit was almost the same. Figure 7.4 shows the evacuation times of each scenario and from the two studies.

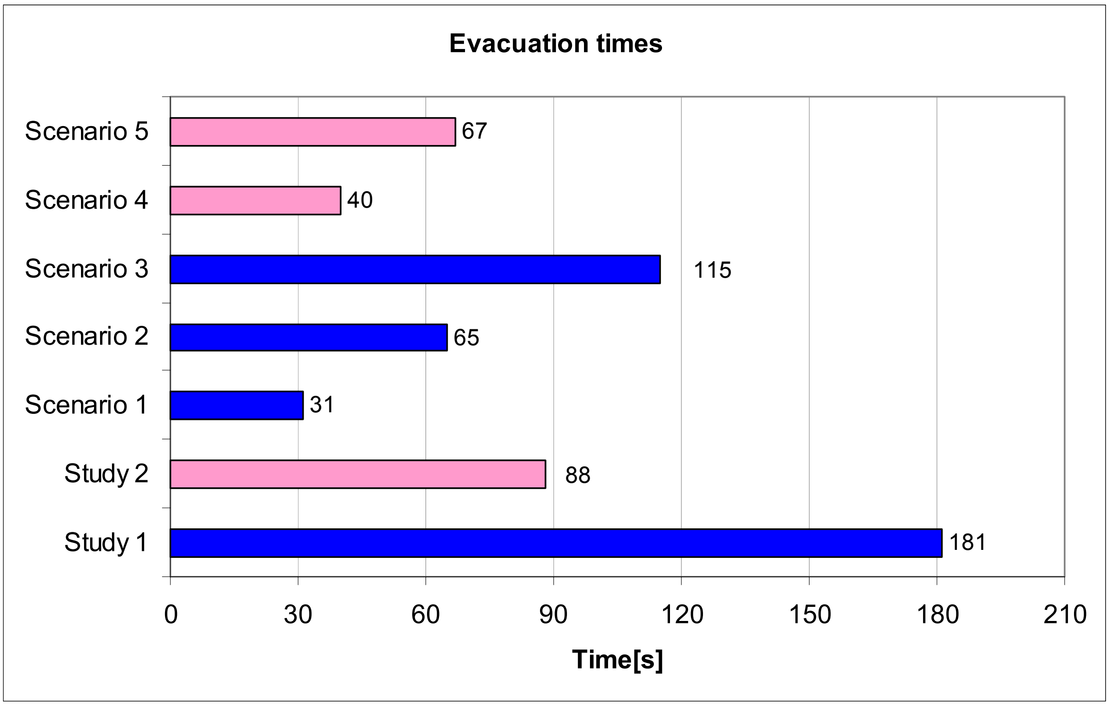


Figure 7.4: Results of each scenario in Simulex for the lecture theatre evacuation.

By comparing the first three scenarios with Study 1, all three scenarios were not even close to the actual data. Although the first two were expected to have a short evacuation time, Scenario 3, which was modelled accordingly to the actual data, was expected to produce a closer results. The difference was approximately a minute. The evacuation times in Scenario 5 and in Study 2 were different by approximately 20 seconds. It must be noted that the use of the pre-movement distribution might be one of the factors to cause the difference, especially in the case such as Study 1.

Comparisons were further made in terms of similar response times. Two pairs of scenarios, which are Scenario 1 and 4, and Scenario 2 and 5, were identical except the number of occupants in the theatre. Both comparisons were not significantly different.

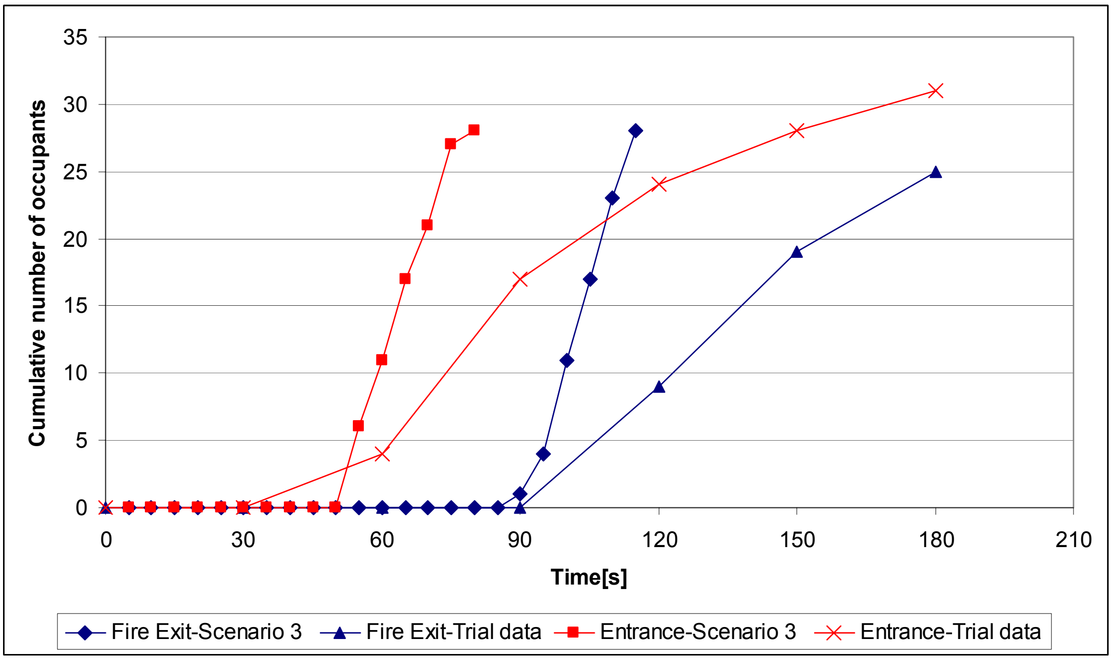


Figure 7.5: Comparison of flow rates at each exit in Scenario 3 and the trial data.

The results also showed that the flow rates at both exits were higher compared to the trial data (Figure 7.5). In Simulex, the flow rate through both exits was approximately 1 ppl/s; whereas in the trial data, the flow rate was approximately 0.28 ppl/s (one person every 3 seconds).

7.2 Modelling with EvacuatioNZ

7.2.1 Methodology and assumptions

In the EvacuatioNZ modelling, the same methodology and assumptions were made as in the Simulex modelling for the inputs. Initially, the theatre was represented as a single node, which resulted in an evacuation time of less than 30 seconds. However, this network model was not an appropriate description of a lecture theatre setting and thus resulted in a short evacuation time. The seating rows and the limited walking paths to the exits restricted the occupants' movement. Therefore, the theatre was represented as a network of nodes (Figure 7.6). The dimensions of the setting were referred to Figure 7.2.

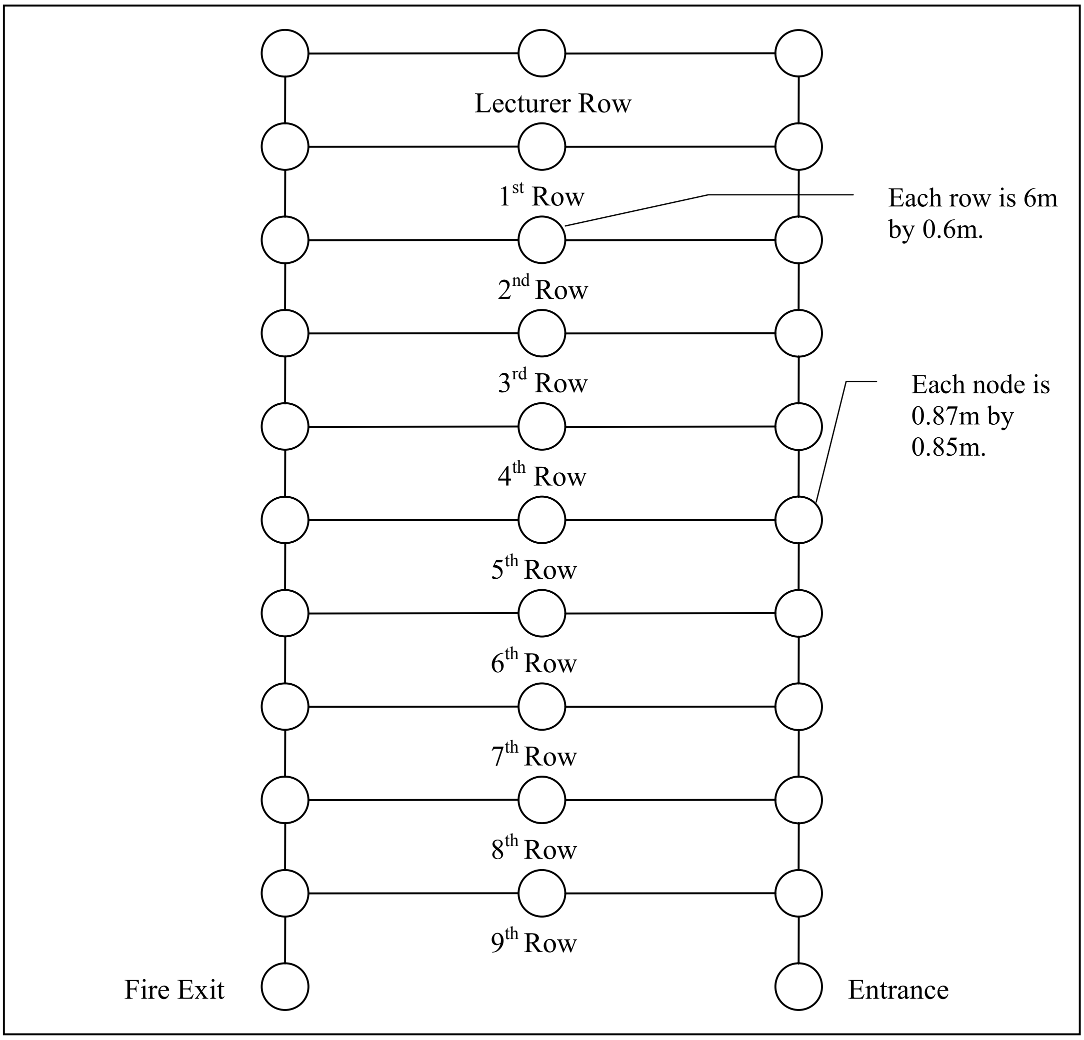


Figure 7.6: The network of nodes for the theatre setting.

The middle node represents each seating row. The two nodes beside it represent the aisle at the section. Therefore, there are 32 nodes and 40 connections in total. The numbers of occupants in each row and the dimensions of the setting were in accordance with those in Simulex. The occupants have two exit choices, that is, the "preferred" and the "exit sign" routes. Therefore, the connections at either side of the rows were specified as the "preferred" and "exit sign" accordingly. In the POPULATE file, 55% of the occupants in each node would choose the "preferred" route and 45% would choose the "exit sign" route. This would simulate the evacuation from Study 1. The walking speed and the maximum node density used were 1.2 m/s and 3 ppl/m². A higher occupant density was assumed in this case because in a tight space like a lecture theatre setting, it is likely to have higher occupants crowding density. Five scenarios have been simulated similar to Simulex (Table 7.3).

Problems occurred during the first attempt of running a scenario. The simulated evacuation times were too long (about 300 to 400 seconds). It was later found that the aisle leading to the entrance was the problem. It was due to the area of that aisle being too small to allow the occupants to walk smoothly. There was no such problem with the other aisle. Therefore, the width was changed from 0.65 to 0.85m (same as the other aisle). The other problems were the exit behaviour features ("preferred" and "exit sign") and the simulations flaws. These problems were discussed previously in Chapter 4.

Convergence tests were done before analysing the results. 500 simulations were run in all five scenarios. Due to the flaws in the exit behaviour components, half of the results were not exactly as specified in the input files and the other half were very different. Therefore the former 250 simulations were used for convergence testing and justified that 250 simulations was sufficient. The former half of the results did not exactly produce 55% and 45% ratio at both exits. The reason has been discussed in Chapter 4. The remaining half showed that only one exit was used.

Refer to APPENDIX D for examples of EvacuatioNZ input files.

7.2.2 Results

In this complicated network of nodes, the "preferred" or "exit sign" algorithm is not adequate to simulate the desired scenario. Figure 7.7 demonstrates the typical EvacuatioNZ results for the lecture theatre simulations. It shows the frequency of each evacuation time and the two distinct distributions. The circled distribution was the results of using one exit, which is the fire exit.

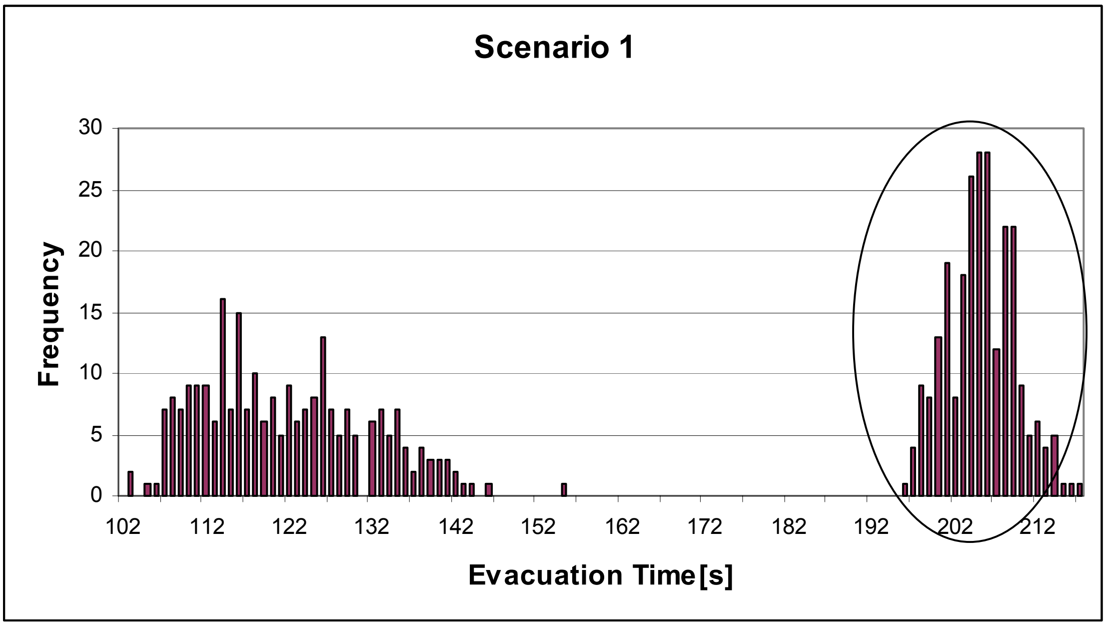
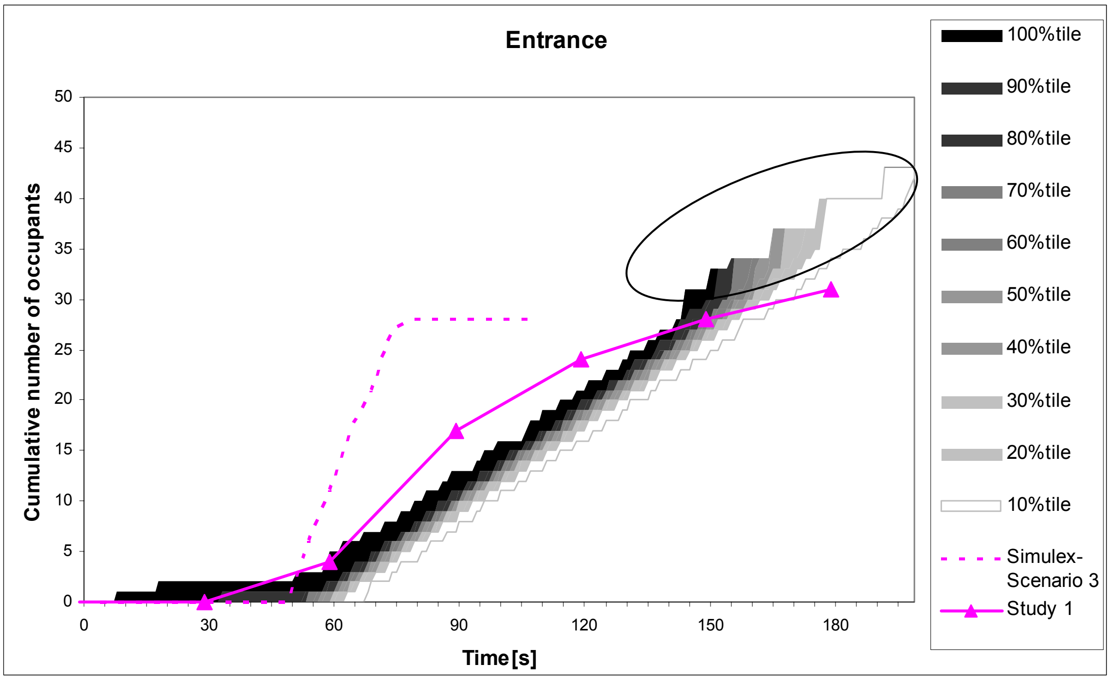


Figure 7.7: An example of EvacuatioNZ results for the lecture theatre simulations.

Figure 7.8 shows the flow distributions and the results from Simulex and trial data (Study 1). It is the results for Scenario 3, where the occupants that used the entrance have a pre-movement time of 45 seconds and 90 seconds for those who used the fire exit. As only Study 1 had available flow data, thus, only this scenario is under discussion. This would justify how accurate the evacuation time both evacuation models can predict. The graph shows the flow rates of the actual and EvacuatioNZ were very close at both exits; whereas Simulex has a significantly higher flow rate at both the exit.

The graphs also indicated how many occupants had used each of the exits. More occupants used the entrance, but there is no significant difference at the usage of both exits. The circled area in Figure 7.8 indicates that the frequencies decreases as the number of occupant used the entrance increase.



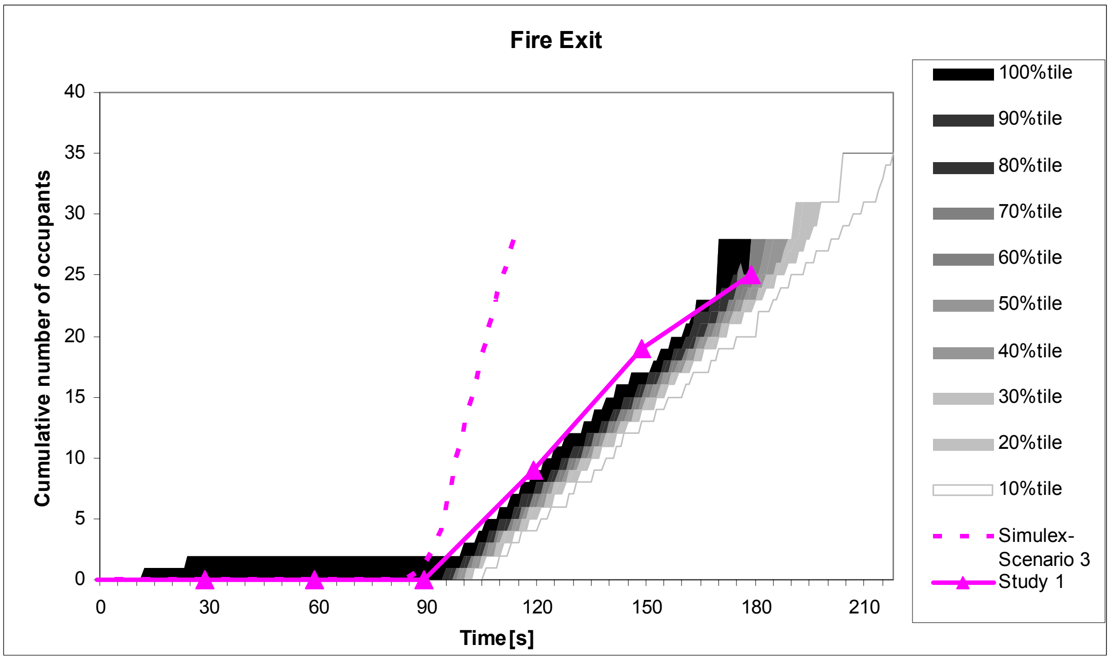


Figure 7.8: Cumulative probability distributions of the flow of occupants at the entrance and the fire exit (Scenario 3).

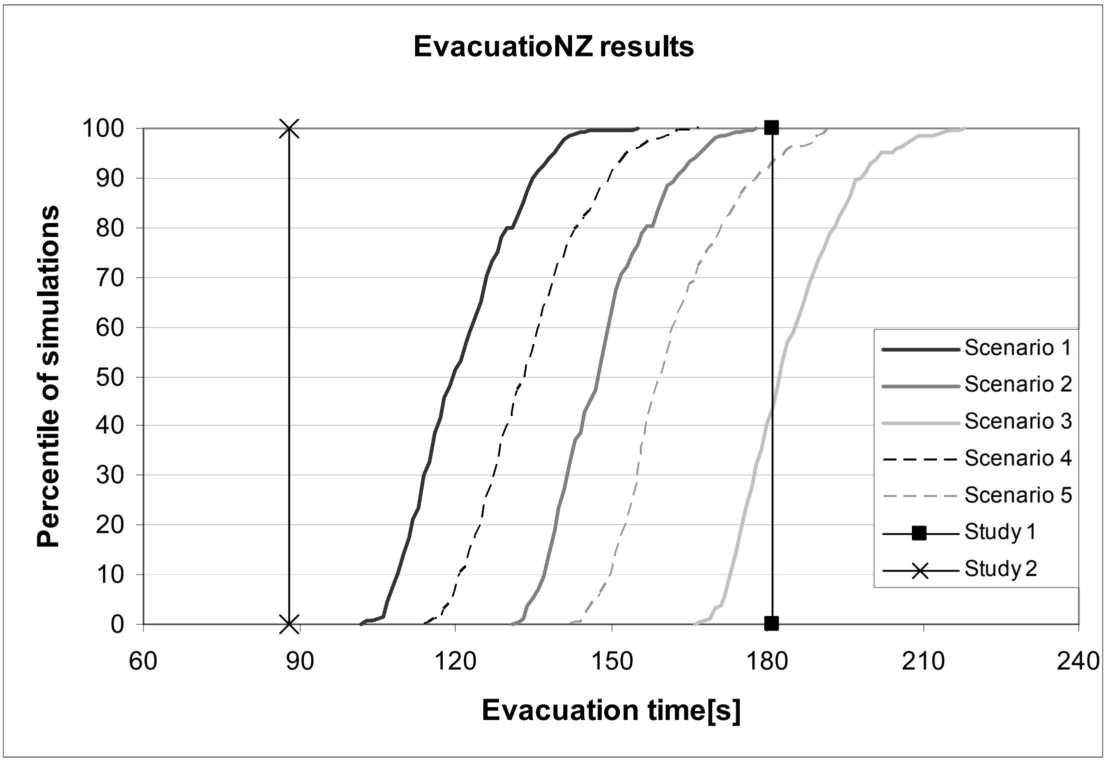


Figure 7.9: Results of each scenario in EvacuatioNZ for the lecture theatre evacuation.

Figure 7.9 shows results of all the scenarios in EvacuatioNZ and the two actual evacuation times. Scenario 1, 2 and 3 have 56 occupants and Scenario 4 and 5 have 63 occupants. By comparing Scenario 1,2,3 and Study 1 (same number of occupants), it was anticipated that Scenario 3 was the most accurate representative of the actual event. The recorded time from Study 1 lay at the 50 percentile (median) of Scenario 3.

The results lay between the two actual data. In a way, they have underestimated the evacuation time, yet overestimated at the same time. Generally, EvacuatioNZ overestimates the evacuation time. Even without a pre-movement time (Scenario 1 and Scenario 4), the results were longer compared to Study 2. This is certainly not the case with Simulex. In Section 7.1.2, the results of all the scenarios except Scenario 3, were shorter than Study 2.

8. General discussion

From the two evacuation simulations analyses, Simulex has a faster flow rate and shortest evacuation time. EvacuatioNZ generally gives a more accurate representation of the actual events than Simulex. However, one should note that the PDL evacuation simulations were based on a single trial data of the event and two trial data in the lecture theatre simulations.

If the user were to predict the evacuation time of a lecture theatre identical to the theatre setting in this report, using an appropriate pre-movement time (30 seconds from two different sources) and its distribution (such as a skew distribution) in EvacuatioNZ, the probabilistic results would have covered all the possible scenarios. The two evacuation times of the lecture theatre recorded from the two studies (181 seconds and 88 seconds) might lie in the distribution. Therefore, designers and fire engineers would be able to evaluate their designs based on a probabilistic assessment.

The maximum connection length was used in all the simulations using EvacuatioNZ. This length was assumed as the distance for an occupant in the most remote position to the furthest exit. Generally, it will be the sum of the node dimensions. However, a node such as a corridor or a pathway, the distance would be its length. The use of the maximum connection length may result in longer evacuation times. It may not represent a realistic walking path. For example, there are two interconnected rooms and only one exit that is in the second room but very close the interconnected door. The occupants from the first room would have to travel a longer distance than they needed to. If the room is small, it would not have significant effect, whereas a large room, then results may be inaccurate. This assumption, however, did simulate a good approximation to both the actual evacuations.

To simulate a tight space like a lecture theatre in EvacuatioNZ, reasonable assumptions must be made. The area of each node will make a significant difference in the evacuation time, which is the case in the first attempt of simulating the lecture theatre evacuation. The maximum node density is also an important variable in this case. As the theatre was modelled into a network of nodes, the number of occupants in a node is very limited due to the small area of each node, especially in the aisle. In this case, the occupant density in the aisle would as well have the same density as the local occupant density. It has certainly been justified by the accuracy of the results to the actual data.

8.1 Limitations of EvacuatioNZ

The EvacuatioNZ model is working satisfactorily and producing comparable results despite the limitations with the “preferred route” or “exit sign” exit behaviour type. These behaviour types can only perform well to a certain extent, which is a simple straightforward network. For example, it is working perfectly well in the PDL evacuation, but not in the lecture theatre evacuation.

At this stage, the limitations in the current program would be the workability of those exit behaviour types and the problems that were mentioned in Chapter 3 and 4. The basic components of movement are working satisfactorily. Although EvacuatioNZ allows flexibility in constructing the input files, some features are not fully incorporated in the program, thus they need further testing. However, it is sufficient to simulate buildings such as those at PDL site. Examples of constructing a fully-working input files can be obtained from the PDL evacuation simulations.

Also, EvacuatioNZ is unable to model a lecture theatre or setting similar to it accurately as a single node, otherwise it produces encouraging and accurate results. Therefore, this current version (Version 1.01) of the evacuation model can be used for design purposes under certain circumstances. The user must know the limitations of the evacuation model and proceed with care. The user should be aware of the assumptions and the methodology that were used in EvacuatioNZ to produce such results in the report. One can expect that EvacuatioNZ would simulate a result close to an actual event that is similar to the input data.

8.2 Further testing

- The major adjustment of the model is the "preferred" or "exit sign" exit behaviour type. One of the adjustments is to make the route a one-way direction.

- General ways of constructing the POPULATE file should be tested again to ensure that they are fully working.

- The 'time step' feature is not fully working in the program. In this current version, it only works at a one-second time step. Therefore, the feature needs adjustment.

- Additional distributions for pre-movement time should be included in the program, such as a skewed distribution.

- EvacuatioNZ is currently unable to model a lecture theatre or setting similar to it accurately as a single node. Further research should be done on the model so that it can take into account the complexity of the room setting.

9. Conclusions

- This current version of EvacuatioNZ has been tested and it is reassured that the problems in the previous version have been resolved, such as correcting the travelling speed on the stairs. New approaches and components have been added to the model to increase its functional value.

- Component testing on the model has shown that the combinations of exit behaviour components are working satisfactorily except the “Preferred” route, which needs further adjustments.

- Two human behavioural aspects have incorporated in EvacuatioNZ. The model is able to simulate a staged or controlled evacuation and a preferred route. Although the preferred route does not work adequately, it still is able to simulate a simple evacuation.

- Results from the two evacuation simulations show Simulex has a faster flow rate and a quicker evacuation time. EvacuatioNZ results generally are more accurate representations of the actual events compared with Simulex results. They also show that the pre-movement time is an important factor to the overall evacuation time.

- The current version (Version 1.01) of the evacuation model can be used for design purposes under certain circumstances. Users must know the limitations of the evacuation model and proceed with care.

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APPENDIX A: Component testing input files

EvacuatioNZ input files for local occupant density testing:

(a) MAP file

```
<EvacuatioNZ_Map version="1.01">
	<Description>Single door test</Description>
	<Node exists="Yes">
		<Name>Room</Name>
		<Ref>1</Ref>
		<Length>22.36</Length>
		<Width>22.36</Width>
	</Node>
	<Node exists="Yes">
		<Name>Exit</Name>
		<Ref>2</Ref>
		<NodeType>Safe</NodeType>
		<!-- dimensions are not required for a safe Node -->
	</Node>
	<Connection exists="Yes">
		<Name>TheLink</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>0.0</Length>
		<ConnectionType type="Door">
			<Width>1.0</Width>
		</ConnectionType>
	</Connection>
</EvacuatioNZ_Map>
```

(b) POPULATE file

```
<EvacuatioNZ_Populate version="1.01">
	<Definition>
		<People>100</People>
		<Log>Yes</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>800</People>
		<Log>No</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
```

```xml
        <People>100</People>
        <Log>Yes</Log>
        <Node type="single">1</Node>
        <PersonType>
            <Name>Normal</Name>
            <Probability>100</Probability>
        </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATION file

```xml
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint
(University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
    <TimeMax>12000</TimeMax>
    <TimeStep>1</TimeStep>
    <MaxNodeDensity>2.0</MaxNodeDensity>
    <DoorFlow>Maclennan</DoorFlow>
    <OccupantDensityModel localOccupantDensity="3.0">Mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

(d) SCENARIO file

```xml
<EvacuatioNZ_Scenario version="1.01">
    <Simulations>20</Simulations>
    <DumpEvacuationTimes>Yes</DumpEvacuationTimes>
    <RandomStartPosition>Yes</RandomStartPosition>
    <Files>
        <Simulation>simulation.xml</Simulation>
        <PostProcess>pp template.xml</PostProcess>
        <Populate>populate.xml</Populate>
    </Files>
</EvacuatioNZ_Scenario>
```

(e) PERSON TYPE file

```xml
<EvacuatioNZ_PersonType version="1.01">
    <PersonType name="Normal">
        <Speed>1.20</Speed>
        <ExitBehaviour>Default</ExitBehaviour>
        <Attribute>Disabled</Attribute>
    </PersonType>
</EvacuatioNZ_PersonType>
```

(f) EXIT BEHAVIOUR file

```xml
<EvacuatioNZ_ExitBehaviour version="1.01">
    <ExitBehaviour name="Default">
        <ExitBehaviourType type="MinNodesToSafe">
            <Probability>100</Probability>
        </ExitBehaviourType>
    </ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

EvacuatioNZ input files for Figure 4.2:

(a) MAP file


```xml
<EvacuatioNZ_Map version="1.01">
        <Description>EG#3-Case 1</Description>
        <Node exists="Yes">
                <Name>Room_1</Name>
                <Ref>1</Ref>
                <Length>10</Length>
                <Width>10</Width>
        </Node>
        <Node exists="Yes">
                <Name>Room_2</Name>
                <Ref>2</Ref>
                <Length>10</Length>
                <Width>10</Width>
        </Node>

        <Node exists="Yes">
                <Name>Exit</Name>
                <Ref>3</Ref>
                <NodeType>Safe</NodeType>
        </Node>
        <Connection exists="Yes">
                <Name>Route_1</Name>
                <NodeRef>1</NodeRef>
                <NodeRef>2</NodeRef>
                <Length>10</Length>
                <ConnectionType type="Door">
                        <Width>1.0</Width>
                </ConnectionType>
                <ConnectionChoice type="Preferred"/>
        </Connection>
        <Connection exists="Yes">
                <Name>Route_2</Name>
                <NodeRef>2</NodeRef>
                <NodeRef>3</NodeRef>
                <Length>10</Length>
                <ConnectionType type="Door">
                        <Width>1.0</Width>
                </ConnectionType>
        <ConnectionChoice type="Preferred"/>
        </Connection>
</EvacuatioNZ_Map>
```


(b) POPULATE file


```xml
<EvacuatioNZ_Populate version="1.01">
<Definition>
                <People>100</People>
                <Log>no</Log>
                <Node type="single">1</Node>
                <PersonType>
                        <Name>Normal</Name>
                        <Probability>100</Probability>
                </PersonType>
        </Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATION file


```xml
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint
(University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


(d) SCENARIO file


```xml
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>1</Simulations>
	<DumpEvacuationTimes>No</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


(e) PERSON TYPE file


```xml
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
</EvacuatioNZ_PersonType>
```


(f) EXIT BEHAVIOUR file


```xml
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="Preferred">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

EvacuatioNZ input files for Figure 4.3:

(a) MAP file


```
<EvacuatioNZ_Map version="1.01">
	<Description>Example# 3</Description>
	<Node exists="Yes">
		<Name>Room_1</Name>
		<Ref>1</Ref>
		<Length>10</Length>
		<Width>10</Width>
	</Node>
	<Node exists="Yes">
		<Name>Room_2</Name>
		<Ref>2</Ref>
		<Length>10</Length>
		<Width>10</Width>
	</Node>
	<Node exists="Yes">
		<Name>Exit_1</Name>
		<Ref>3</Ref>
		<NodeType>Safe</NodeType>
	</Node>
	<Node exists="Yes">
		<Name>Exit_2</Name>
		<Ref>4</Ref>
		<NodeType>Safe</NodeType>
	</Node>
	<Connection exists="Yes">
		<Name>Route_1</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>10</Length>
		<ConnectionType type="Door">
			<Width>1.0</Width>
		</ConnectionType>
		<ConnectionChoice type="Preferred"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_2</Name>
		<NodeRef>2</NodeRef>
		<NodeRef>3</NodeRef>
		<Length>6</Length>
		<ConnectionType type="Door">
			<Width>1.0</Width>
		</ConnectionType>
		<ConnectionChoice type="Preferred"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_3</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>4</NodeRef>
		<Length>6</Length>
		<ConnectionType type="Door">
			<Width>1.0</Width>
		</ConnectionType>
	</Connection>
</EvacuatioNZ_Map>
```

(b) POPULATE file

```
<EvacuatioNZ_Populate version="1.01">
	<Definition>
		<People>100</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATION file

```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint
(University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

(d) SCENARIO file

```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>1</Simulations>
	<DumpEvacuationTimes>No</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```

(e) PERSON TYPE file

```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
</EvacuatioNZ_PersonType>
```

(f) EXIT BEHAVIOUR file

```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="Preferred">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

EvacuatioNZ input files for Figure 4.6:

(a) MAP file


```
<EvacuatioNZ_Map version="1.01">
    <Description>"Two Exit
Choices"</Description>
    <Node exists="Yes">
        <Name>Room_1</Name>
        <Ref>1</Ref>
        <Length>10</Length>
        <Width>10</Width>
    </Node>
    <Node exists="Yes">
        <Name>Room_2</Name>
        <Ref>2</Ref>
        <Length>10</Length>
        <Width>10</Width>
    </Node>
    <Node exists="Yes">
        <Name>Room_3</Name>
        <Ref>3</Ref>
        <Length>10</Length>
        <Width>10</Width>
    </Node>
    <Node exists="Yes">
        <Name>Exit_1</Name>
        <Ref>4</Ref>
        <NodeType>Safe</NodeType>
    </Node>
    <Node exists="Yes">
        <Name>Exit_2</Name>
        <Ref>5</Ref>
        <NodeType>Safe</NodeType>
    </Node>
    <Connection exists="Yes">
        <Name>Route_1</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>2</NodeRef>
        <Length>10</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>Route_2</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>3</NodeRef>
        <Length>10</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>Route_3</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>4</NodeRef>
        <Length>20</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
    </Connection>
    <Connection exists="Yes">
        <Name>Route_4</Name>
        <NodeRef>3</NodeRef>
        <NodeRef>5</NodeRef>
        <Length>5</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
    </Connection>
</EvacuatioNZ_Map>
```


(b) POPULATE file


```
<EvacuatioNZ_Populate version="1.01">
    <Definition>
        <People>100</People>
        <Log>no</Log>
        <Node type="single">1</Node>
        <PersonType>
            <Name>Normal</Name>
            <Probability>100</Probability>
        </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATION file


```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint
(University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>1000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


(d) SCENARIO file


```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>2000</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


(e) PERSON TYPE file

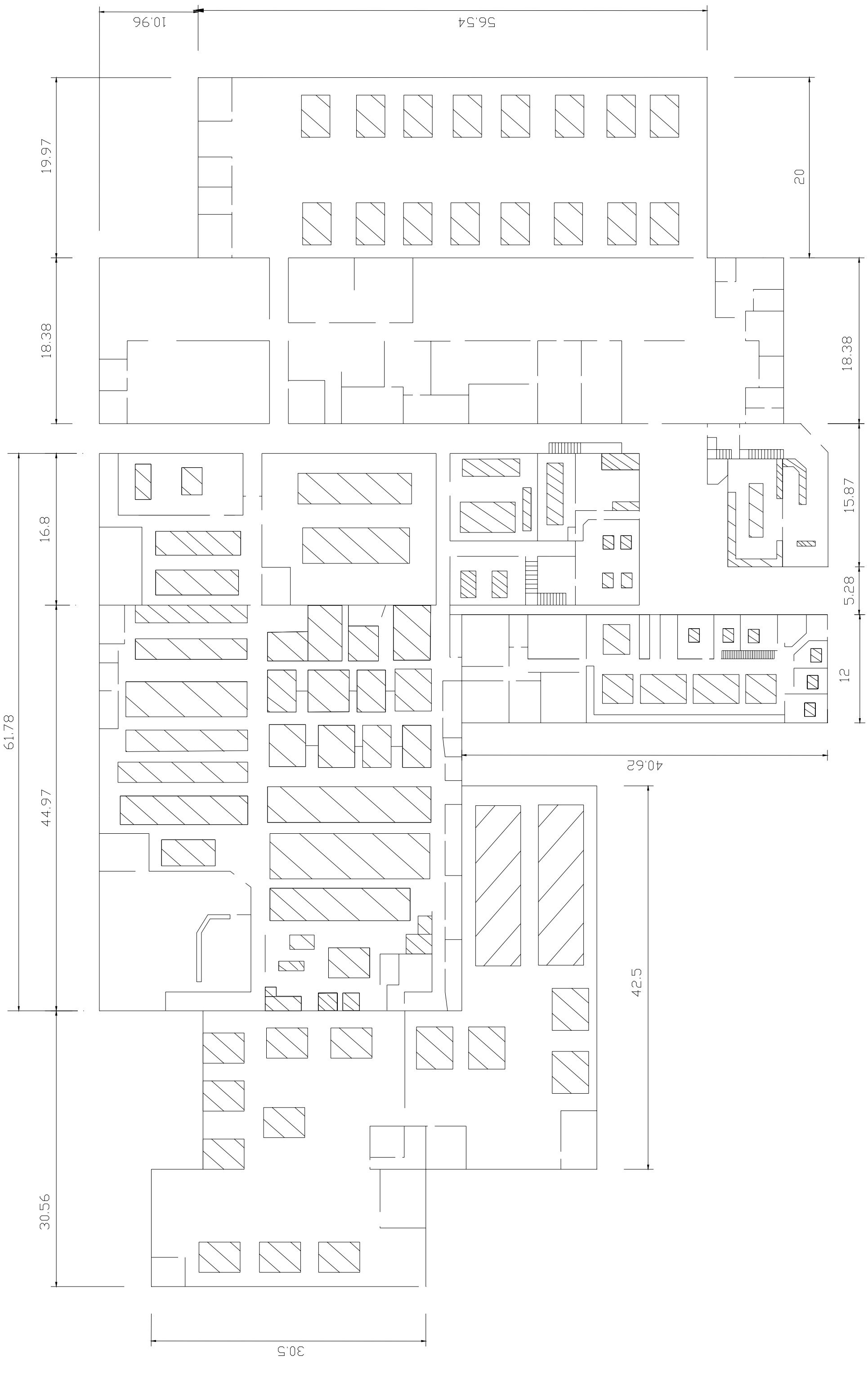

```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>

</EvacuatioNZ_PersonType>
```


(f) EXIT BEHAVIOUR file

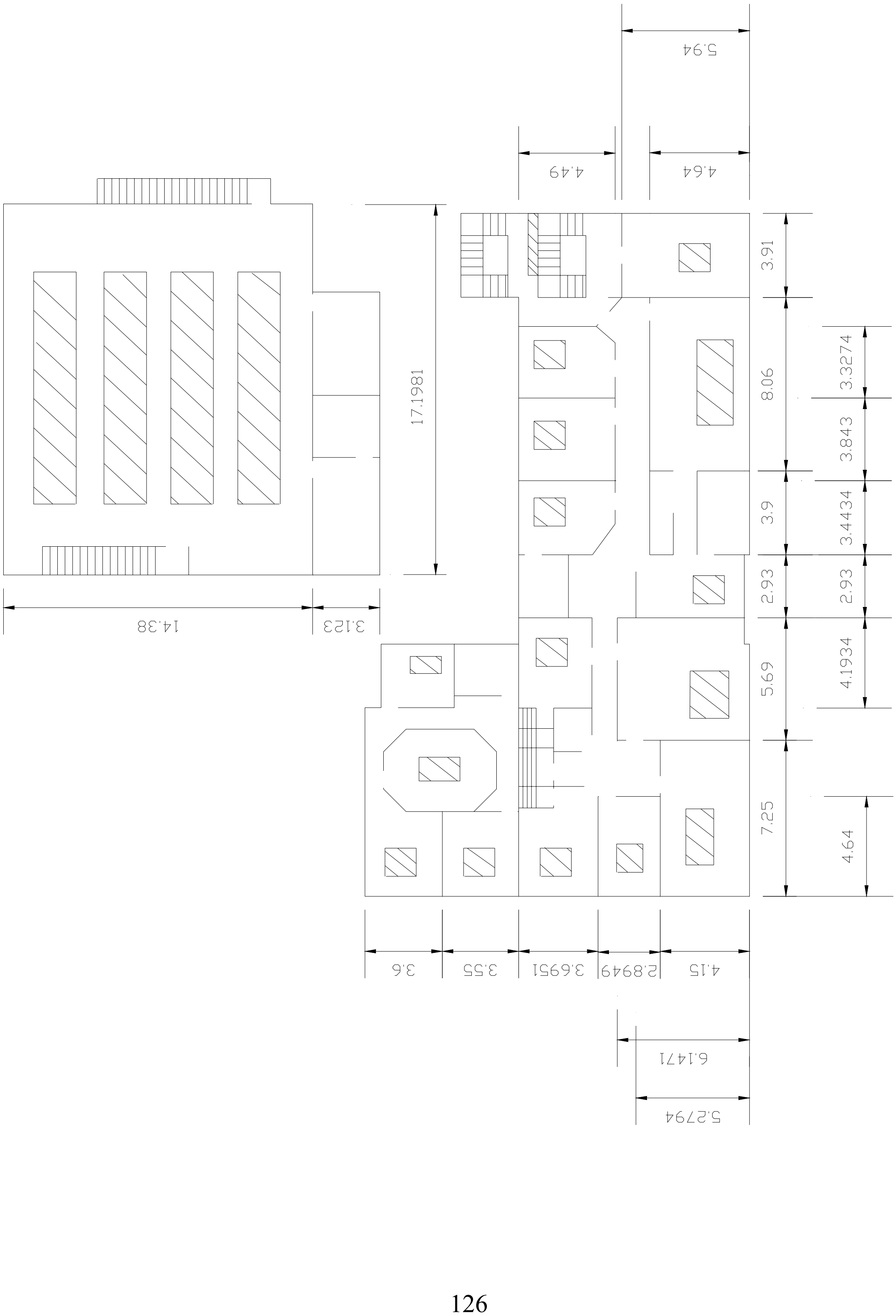

```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="MinDistanceToSafe">
			<Probability>50</Probability>
		</ExitBehaviourType>
		<ExitBehaviourType type="MinNodesToSafe">
			<Probability>50</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

APPENDIX B: Raw data from the Exercise

Ground level plan of PDL site:



First level plan of PDL site:



Exit 1:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
19	1	1
20	1	2
21	1	3
29	1	4
38	1	5
39	1	6
41	1	7
42	1	8
44	1	9
45	1	10
48	1	11
48	1	12
49	1	13
51	1	14
52	1	15
55	1	16
56	1	17
60	1	18
61	1	19
63	1	20
66	1	21
104	1(Warden)	22
113	1(Warden)	23
129	(Re-entry)	23
135	3	26
137	1	27
190	(Re-entry)	27
217	1	28
247	0 (Alarm ended)	28

Exit 2:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
17	3	3
21	3	6
26	4	10
38	3	13
41	1	14
70	1	15
92	4	19
96	1(Warden)	20
100	1	21
248	0 (Alarm ended)	21

Exit 3:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
15	1	1
19	1	2
25	1	3
26	1	4
26	1	5
27	1	6
32	1	7
33	1	8
37	1	9
40	1	10
40	1	11
41	1	12
42	1	13
47	1	14
61	1	15
67	1	16
69	1	17
72	1	18
73	1	19
81	1	20
82	1	21
87	1	22
146	1	23
149	1(Warden)	24
151	1	25
155	1	26
256	0 (Alarm ended)	26

Exit 4:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
21	1	1
24	2	3
27	1	4
28	1	5
34	1	6
39	2	8
41	3	11
43	3	14
46	4	18
47	1	19
48	2	21
50	1	22
52	3	25
54	2	27
57	5	32
59	4	36
61	2	38
62	2	40
64	4	44
68	5	49
72	5	54
75	5	59
77	5	64
80	5	69
83	5	74
84	2	76
89	1	77
98	1	78
102	1	79
106	2	81
108	2	83
110	1	84
111	1	85
120	1(Warden)	86
121	1(Warden)	87
122	1(Warden)	88
124	1	89
132	2	91
257	1	92
258	0 (Alarm ended)	92

Exit 5:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
12	1	1
18	1(Warden)	2
32	1(Warden)	3
37	1(Warden)	4
42	1(Warden)	5
45	1(Warden)	6
49	1(Warden)	7
55	1(Warden)	8
64	1(Warden)	9
86	1(Warden)	10
248	0 (Alarm ended)	10

Exit 6:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
29	3	3
32	2	5
39	4	9
43	3	12
53	9	21
54	9	30
61	9	39
65	5	44
74	8	52
82	1	53
93	1	54
249	0 (Alarm ended)	54

Exit 7:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0 (Alarm started)	0
33	1	1
37	2	3
40	1	4
42	2	6
44	1	7
45	2	9
46	1	10
47	1	11
48	1	12
49	1	13
50	2	15
51	1	16
51	2	18
52	1	19
53	2	21
53	1	22
55	1	23
57	1	24
58	1	25
59	1	26
60	1	27
61	4	31
61	5	36
63	2	38
64	1	39
65	4	43
65	2	45
66	2	47
67	3	50
68	2	52
70	3	55
71	2	57
72	1	58
72	1	59
73	2	61
74	2	63
74	2	65
75	2	67
75	1	68
76	2	70
78	2	72
80	1(Warden)	73
82	3	76
83	4	80
83	1	81
84	2	83
85	1	84
87	1	85
88	2	87
89	4	91
91	1	92
92	2	94
92	1	95
93	5	100
94	1	101
95	2	103
97	1	104
97	1	105
98	1	106
98	1	107
99	1	108
99	1	109
99	1	110
100	3	113
102	2	115
113	1	116
117	1	117
117	1	118
119	1	119
122	1	120
123	3	123
124	1	124
127	1	125
130	1	126
145	1	127
257	0 (Alarm ended)	127

Exit 8:

Time (s)	Observation (no. of people)	Cumulative No. of people
0	0	0
257	0	0

APPENDIX C: EvacuatioNZ input files for the PDL evacuation simulation

"A"

(a) MAP file

```
<EvacuatioNZ_Map version="1.01">
	<Description>Building "A" </Description>
	<Node exists="Yes">
		<Name>A1</Name>
		<Ref>1</Ref>
		<Length>42.5</Length>
		<Width>15</Width>
	</Node>
	<Node exists="Yes">
		<Name>A2</Name>
		<Ref>2</Ref>
		<Length>27</Length>
		<Width>30</Width>
	</Node>
	<Node exists="Yes">
		<Name>Exit3</Name>
		<Ref>3</Ref>
		<NodeType>Safe</NodeType>
	</Node>
	<Connection exists="Yes">
		<Name>Route_1</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>57</Length>
		<ConnectionType type="Door">
			<Width>2.0</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_2</Name>
		<NodeRef>2</NodeRef>
		<NodeRef>3</NodeRef>
		<Length>56.5</Length>
		<ConnectionType type="Door">
			<Width>0.78</Width>
		</ConnectionType>
	</Connection>
</EvacuatioNZ_Map>
```

(b) POPULATE file

```
<EvacuatioNZ_Populate version="1.01">
	<Definition>
		<People>9</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>17</People>
		<Log>no</Log>
		<Node type="single">2</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATON file

```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint (University of
Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

(d) SCENARIO file

```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>500</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```

(e) PERSON TYPE file

```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
</EvacuatioNZ_PersonType>
```

(f) EXIT BEHAVIOUR file

```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="MinDistanceToSafe">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

“C&E”

(a) MAP file

```
<EvacuatioNZ_Map version="1.01">
	<Description>Building "C" and Part
"E"</Description>
	<Node exists="Yes">
		<Name>C</Name>
		<Ref>1</Ref>
		<Length>44.97</Length>
		<Width>40.26</Width>
	</Node>
	<Node exists="Yes">
		<Name>E1</Name>
		<Ref>2</Ref>
		<Length>16.8</Length>
		<Width>37.41</Width>
	</Node>
	<Node exists="Yes">
		<Name>E2</Name>
		<Ref>3</Ref>
		<Length>16.8</Length>
		<Width>10</Width>
	</Node>

	<Node exists="Yes">
		<Name>Corridor</Name>
		<Ref>4</Ref>
		<Length>18</Length>
		<Width>3.3</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor1</Name>
		<Ref>5</Ref>
		<Length>20.9</Length>
		<Width>3.3</Width>
	</Node>
	<Node exists="Yes">
		<Name>Exit7</Name>
		<Ref>6</Ref>
		<NodeType>Safe</NodeType>
	</Node>
	<Connection exists="Yes">
		<Name>Route_1</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>2</NodeRef>
		<Length>66.97</Length>
		<ConnectionType type="Door">
			<Width>1.16</Width>
```

```
			</ConnectionType>
			<ConnectionChoice
type="Preferred"/>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_2</Name>
			<NodeRef>2</NodeRef>
			<NodeRef>4</NodeRef>
			<Length>38.8</Length>
			<ConnectionType type="Door">
				<Width>1.5</Width>
			</ConnectionType>
			<ConnectionChoice
type="Preferred"/>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_3</Name>
			<NodeRef>4</NodeRef>
			<NodeRef>6</NodeRef>
			<Length>18</Length>
			<ConnectionType type="Door">
				<Width>3.3</Width>
			</ConnectionType>
			<ConnectionChoice
type="Preferred"/>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_4</Name>
			<NodeRef>1</NodeRef>
			<NodeRef>3</NodeRef>
			<Length>85.23</Length>
			<ConnectionType type="Door">
				<Width>1.5</Width>
			</ConnectionType>
			</Connection>
		<Connection exists="Yes">
			<Name>Route_5</Name>
			<NodeRef>3</NodeRef>
			<NodeRef>5</NodeRef>
			<Length>26.8</Length>
			<ConnectionType type="Door">
				<Width>1.55</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_6</Name>
			<NodeRef>5</NodeRef>
			<NodeRef>4</NodeRef>
			<Length>20.9</Length>
			<ConnectionType type="Door">
				<Width>3.3</Width>
			</ConnectionType>
		</Connection>
<!-- "Front of "E" "-->
<Node exists="Yes">
	<Name>Technical Support</Name>
	<Ref>7</Ref>
	<Length>11.3</Length>
	<Width>8.4</Width>
</Node>
<Node exists="Yes">
	<Name>e.BOS</Name>
	<Ref>8</Ref>
	<Length>11.3</Length>
	<Width>8.4</Width>
</Node>
<Node exists="Yes">
	<Name>Corridor</Name>
	<Ref>9</Ref>
	<Length>4.7</Length>
	<Width>1.0</Width>
</Node>
<Node exists="Yes">
	<Name>CourtYard</Name>
	<Ref>10</Ref>
	<Length>11.14</Length>
	<Width>5.34</Width>
</Node>
<Node exists="Yes">
	<Name>Common</Name>
	<Ref>11</Ref>
	<Length>11.13</Length>
	<Width>5.34</Width>
</Node>
<Node exists="Yes">
	<Name>Exit6</Name>
	<Ref>15</Ref>
	<NodeType>Safe</NodeType>
</Node>
<Connection exists="Yes">
	<Name>Route_7</Name>
	<NodeRef>7</NodeRef>
	<NodeRef>9</NodeRef>
	<Length>15</Length>
	<ConnectionType type="Door">
		<Width>0.78</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_8</Name>
	<NodeRef>8</NodeRef>
	<NodeRef>9</NodeRef>
	<Length>15</Length>
	<ConnectionType type="Door">
		<Width>0.78</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_9</Name>
	<NodeRef>9</NodeRef>
	<NodeRef>10</NodeRef>
	<Length>4.7</Length>
	<ConnectionType type="Door">
		<Width>0.78</Width>
	</ConnectionType>
</Connection>
```

```xml
<Connection exists="Yes">
	<Name>Route_10</Name>
	<NodeRef>10</NodeRef>
	<NodeRef>11</NodeRef>
	<Length>11.14</Length>
	<ConnectionType type="Door">
		<Width>5.34</Width>
	</ConnectionType>
</Connection>


<!-- "F" old cafe -->
<Node exists="Yes">
	<Name>Office</Name>
	<Ref>12</Ref>
	<Length>17.25</Length>
	<Width>17.5</Width>
</Node>
<Node exists="Yes">
	<Name>Stairs</Name>
	<Ref>13</Ref>
	<Width>1.18</Width>
	<Length>8.0</Length>
</Node>
<Node exists="Yes">
	<Name>CourtYard1</Name>
	<Ref>14</Ref>
	<Length>26.87</Length>
	<Width>5.34</Width>
</Node>
<Connection exists="Yes">
	<Name>Route_11</Name>
	<NodeRef>12</NodeRef>
	<NodeRef>13</NodeRef>
	<Length>29.65</Length>
	<ConnectionType type="Door">
		<Width>0.88</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_12</Name>
	<NodeRef>13</NodeRef>
	<NodeRef>14</NodeRef>
	<Length>8</Length>
	<ConnectionType type="Door">
		<Width>1.18</Width>
	</ConnectionType>
	<ConnectionType type="Stairs">
		<Tread>0.28</Tread>
		<Riser>0.18</Riser>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_13</Name>
	<NodeRef>14</NodeRef>
	<NodeRef>11</NodeRef>
	<Length>26.87</Length>
	<ConnectionType type="Door">
		<Width>5.34</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_13</Name>
	<NodeRef>11</NodeRef>
	<NodeRef>15</NodeRef>
	<Length>11.13</Length>
	<ConnectionType type="Door">
		<Width>5.34</Width>
	</ConnectionType>
</Connection>


<!-- Building "H" and "L" -->
<Node exists="Yes">
	<Name>L</Name>
	<Ref>16</Ref>
	<Length>56.54</Length>
	<Width>19.97</Width>
</Node>
<Node exists="Yes">
	<Name>H1</Name>
	<Ref>17</Ref>
	<Length>55</Length>
	<Width>18.38</Width>
</Node>
<Node exists="Yes">
	<Name>Hall1</Name>
	<Ref>18</Ref>
	<Length>9</Length>
	<Width>2.1</Width>
</Node>
<Node exists="Yes">
	<Name>H2</Name>
	<Ref>19</Ref>
	<Length>18.9</Length>
	<Width>18.38</Width>
</Node>
<Node exists="Yes">
	<Name>Hall2</Name>
	<Ref>20</Ref>
	<Length>9.38</Length>
	<Width>2.1</Width>
</Node>
<Node exists="Yes">
	<Name>CourtYard2</Name>
	<Ref>21</Ref>
	<Length>17.5</Length>
	<Width>5.34</Width>
</Node>

<Connection exists="Yes">
	<Name>Route_15</Name>
	<NodeRef>16</NodeRef>
	<NodeRef>18</NodeRef>
	<Length>68.58</Length>
	<ConnectionType type="Door">
		<Width>2.1</Width>
	</ConnectionType>
</Connection>
<Connection exists="Yes">
	<Name>Route_16</Name>
	<NodeRef>16</NodeRef>
	<NodeRef>17</NodeRef>
	<Length>76.51</Length>
	<ConnectionType type="Door">
```

```xml
				<Width>1.5</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_17</Name>
			<NodeRef>18</NodeRef>
			<NodeRef>20</NodeRef>
			<Length>9</Length>
			<ConnectionType type="Door">
				<Width>2.1</Width>
			</ConnectionType>

		</Connection>
		<Connection exists="Yes">
			<Name>Route_18</Name>
			<NodeRef>19</NodeRef>
			<NodeRef>20</NodeRef>
			<Length>28.1</Length>
			<ConnectionType type="Door">
				<Width>2.4</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_19</Name>
			<NodeRef>17</NodeRef>
			<NodeRef>20</NodeRef>
			<Length>64.38</Length>
			<ConnectionType type="Door">
				<Width>2.4</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_20</Name>
			<NodeRef>20</NodeRef>
			<NodeRef>4</NodeRef>
			<Length>9.38</Length>
			<ConnectionType type="Door">
				<Width>2.1</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_3</Name>
			<NodeRef>4</NodeRef>
			<NodeRef>6</NodeRef>
			<Length>18</Length>
			<ConnectionType type="Door">
				<Width>3.3</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_21</Name>
			<NodeRef>17</NodeRef>
			<NodeRef>21</NodeRef>
			<Length>73.38</Length>
			<ConnectionType type="Door">
				<Width>1.5</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_22</Name>
			<NodeRef>21</NodeRef>
			<NodeRef>11</NodeRef>
			<Length>17.5</Length>
			<ConnectionType type="Door">
				<Width>5.34</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_14</Name>
			<NodeRef>11</NodeRef>
			<NodeRef>15</NodeRef>
			<Length>11.13</Length>
			<ConnectionType type="Door">
				<Width>5.34</Width>
			</ConnectionType>
		</Connection>
	</EvacuatioNZ_Map>
```


(b) POPULATE file


```xml
<EvacuatioNZ_Populate version="1.01">
	<!-- Population in "C" and "E" -->
	<Definition>
		<People>79</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>12</People>
		<Log>no</Log>
		<Node type="single">2</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">3</Node>
		<PersonType>
			<Name>Normal1</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>

	<!-- Polpulation in Front "E" and "F" -->
	<Definition>
		<People>10</People>
		<Log>no</Log>
		<Node type="single">7</Node>
		<PersonType>
			<Name>Normal2</Name>
			<Probability>100</Probability>
```

```
		</PersonType>
	</Definition>
	<Definition>
		<People>8</People>
		<Log>no</Log>
		<Node type="single">8</Node>
		<PersonType>
			<Name>Normal2</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>26</People>
		<Log>no</Log>
		<Node type="single">12</Node>
		<PersonType>
			<Name>Normal2</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>

	<!-- Polpulation in "H" and "L" -->
	<Definition>
		<People>22</People>
		<Log>no</Log>
		<Node type="single">16</Node>
		<PersonType>
			<Name>Normal1</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>25</People>
		<Log>no</Log>
		<Node type="single">17</Node>
		<PersonType>
			<Name>Normal1</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>8</People>
		<Log>no</Log>
		<Node type="single">19</Node>
		<PersonType>
			<Name>Normal1</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```


(c) SIMULATION file


```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint (University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


(d) SCENARIO file


```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>500</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


(e) PERSON TYPE file


```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
	<PersonType name="Normal1">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default1</ExitBehaviour>
```

```
		</PersonType>
		<PersonType name="Normal2">
			<Speed>1.20</Speed>
			<ExitBehaviour>Default2</ExitBehaviour>
		</PersonType>
	</EvacuatioNZ_PersonType>
```


(f) EXIT BEHAVIOUR file


```
	<EvacuatioNZ_ExitBehaviour version="1.01">
		<ExitBehaviour name="Default">
			<ExitBehaviourType type="Preferred">
				<Probability>100</Probability>
			</ExitBehaviourType>
		</ExitBehaviour>
		<ExitBehaviour name="Default1">
			<ExitBehaviourType type="MinNodesToSafe">
				<Probability>100</Probability>
			</ExitBehaviourType>
		</ExitBehaviour>
		<ExitBehaviour name="Default2">
			<ExitBehaviourType type="MinDistanceToSafe">
				<Probability>100</Probability>
			</ExitBehaviourType>
		</ExitBehaviour>
	</EvacuatioNZ_ExitBehaviour>
```


“G&S”

(a) MAP file


```
<EvacuatioNZ_Map version="1.01">
	<Description>"Industrial Office"</Description>
	<!-- 1st floor "S" -->
	<Node exists="Yes">
		<Name>R1</Name>
		<Ref>1</Ref>
		<Length>3.94</Length>
		<Width>3.6</Width>
	</Node>
	<Node exists="Yes">
		<Name>R2</Name>
		<Ref>2</Ref>
		<Length>3.94</Length>
		<Width>3.55</Width>
	</Node>
	<Node exists="Yes">
		<Name>R3</Name>
		<Ref>3</Ref>
		<Length>3.4</Length>
		<Width>2.95</Width>
	</Node>
	<Node exists="Yes">
		<Name>Meeting</Name>
		<Ref>4</Ref>
		<Length>5.26</Length>
		<Width>3.83</Width>
	</Node>
	<Node exists="Yes">
		<Name>Hall1</Name>
		<Ref>5</Ref>
		<Length>4.83</Length>
		<Width>0.86</Width>
	</Node>
	<Node exists="Yes">
		<Name>Hall2</Name>
		<Ref>6</Ref>
		<Length>5.9</Length>
		<Width>1.0</Width>
	</Node>
	<Node exists="Yes">
		<Name>Hall3</Name>
		<Ref>7</Ref>
		<Length>3.0</Length>
		<Width>1.03</Width>
	</Node>
	<Node exists="Yes">
		<Name>Stairs</Name>
		<Ref>8</Ref>
		<Width>0.9</Width>
		<Length>6</Length>
	</Node>

	<Connection exists="Yes">
		<Name>Route_1</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>5</NodeRef>
		<Length>7.54</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_2</Name>
		<NodeRef>2</NodeRef>
```

```xml
        <NodeRef>7</NodeRef>
        <Length>7.49</Length>
        <ConnectionType type="Door">
            <Width>0.79</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>Route_3</Name>
        <NodeRef>3</NodeRef>
        <NodeRef>6</NodeRef>
        <Length>6.35</Length>
        <ConnectionType type="Door">
            <Width>0.79</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>Route_4</Name>
        <NodeRef>5</NodeRef>
        <NodeRef>6</NodeRef>
        <Length>4.83</Length>
        <ConnectionType type="Door">
            <Width>1.0</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>Route_5</Name>
        <NodeRef>6</NodeRef>
        <NodeRef>8</NodeRef>
        <Length>5.9</Length>
        <ConnectionType type="Door">
            <Width>0.9</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>Route_6</Name>
        <NodeRef>7</NodeRef>
        <NodeRef>8</NodeRef>
        <Length>3.0</Length>
        <ConnectionType type="Door">
            <Width>0.9</Width>
        </ConnectionType>
</Connection>

<!-- Ground floor "G" -->
<Node exists="Yes">
        <Name>R4</Name>
        <Ref>9</Ref>
        <Length>4.75</Length>
        <Width>3.2</Width>
</Node>
<Node exists="Yes">
        <Name>R5</Name>
        <Ref>10</Ref>
        <Length>3.71</Length>
        <Width>2.86</Width>
</Node>
<Node exists="Yes">
        <Name>R6</Name>
        <Ref>11</Ref>
        <Length>3.6</Length>
        <Width>3.05</Width>
</Node>
<Node exists="Yes">
        <Name>R7</Name>
        <Ref>12</Ref>
        <Length>3.22</Length>
        <Width>3.16</Width>
</Node>
<Node exists="Yes">
        <Name>R8</Name>
        <Ref>13</Ref>
        <Length>4.12</Length>
        <Width>3.94</Width>
</Node>
<Node exists="Yes">
        <Name>R9</Name>
        <Ref>14</Ref>
        <Length>2.95</Length>
        <Width>3.94</Width>
</Node>
<Node exists="Yes">
        <Name>R10</Name>
        <Ref>15</Ref>
        <Length>4.87</Length>
        <Width>4.0</Width>
</Node>
<Node exists="Yes">
        <Name>R11</Name>
        <Ref>16</Ref>
        <Length>21.2</Length>
        <Width>3</Width>
</Node>
<Node exists="Yes">
        <Name>Corridor</Name>
        <Ref>17</Ref>
        <Length>2.25</Length>
        <Width>2</Width>
</Node>
<Node exists="Yes">
        <Name>Corridor1</Name>
        <Ref>18</Ref>
        <Length>4.3</Length>
        <Width>0.9</Width>
</Node>
<Node exists="Yes">
        <Name>Exit 2</Name>
        <Ref>19</Ref>
        <NodeType>Safe</NodeType>
</Node>
<Connection exists="Yes">
        <Name>Route_7</Name>
        <NodeRef>9</NodeRef>
        <NodeRef>16</NodeRef>
        <Length>7.95</Length>
        <ConnectionType type="Door">
            <Width>0.78</Width>
        </ConnectionType>
</Connection>
<Connection exists="Yes">
        <Name>Route_8</Name>
        <NodeRef>10</NodeRef>
        <NodeRef>16</NodeRef>
        <Length>6.57</Length>
        <ConnectionType type="Door">
            <Width>0.78</Width>
```

```
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_9</Name>
			<NodeRef>13</NodeRef>
			<NodeRef>17</NodeRef>
			<Length>8.06</Length>
			<ConnectionType type="Door">
				<Width>0.78</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_10</Name>
			<NodeRef>14</NodeRef>
			<NodeRef>16</NodeRef>
			<Length>6.89</Length>
			<ConnectionType type="Door">
				<Width>0.78</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_11</Name>
			<NodeRef>15</NodeRef>
			<NodeRef>16</NodeRef>
			<Length>8.5</Length>
			<ConnectionType type="Door">
				<Width>0.78</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_12</Name>
			<NodeRef>16</NodeRef>
			<NodeRef>17</NodeRef>
			<Length>21</Length>
			<ConnectionType type="Door">
				<Width>1.7</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_13</Name>
			<NodeRef>8</NodeRef>
			<NodeRef>17</NodeRef>
			<Length>6.0</Length>
			<ConnectionType type="Door">
				<Width>0.9</Width>
			</ConnectionType>
			<ConnectionType type="Stairs">
				<Tread>0.28</Tread>
				<Riser>0.18</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_14</Name>
			<NodeRef>17</NodeRef>
			<NodeRef>18</NodeRef>
			<Length>2.4</Length>
			<ConnectionType type="Door">
				<Width>0.9</Width>
			</ConnectionType>

		</Connection>
		<Connection exists="Yes">
			<Name>Route_15</Name>
			<NodeRef>18</NodeRef>
			<NodeRef>19</NodeRef>
			<Length>4.3</Length>
			<ConnectionType type="Door">
				<Width>0.9</Width>
			</ConnectionType>

		</Connection>
	</EvacuatioNZ_Map>
```


(b) POPULATE file


```
<EvacuatioNZ_Populate version="1.01">
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>2</People>
		<Log>no</Log>
		<Node type="single">2</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
<Definition>
	<People>1</People>
	<Log>no</Log>
		<Node type="single">3</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">9</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">10</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
```

```
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">13</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">14</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">15</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>12</People>
		<Log>no</Log>
		<Node type="single">16</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
</EvacuatioNZ_Populate>
```


(c) SIMULATION file


```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint (University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


(d) SCENARIO file


```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>500</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


(e) PERSON TYPE file


```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
</EvacuatioNZ_PersonType>
```


(f) EXIT BEHAVIOUR file


```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="MinDistanceToSafe">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

“J&U”

(a) MAP file


```
<EvacuatioNZ_Map version="1.01">
	<Description>"Office area"</Description>
	<!-- 1st floor "U" -->
	<Node exists="Yes">
		<Name>R1</Name>
		<Ref>1</Ref>
		<Length>3.7</Length>
		<Width>4.64</Width>
	</Node>
	<Node exists="Yes">
		<Name>R2</Name>
		<Ref>2</Ref>
		<Length>2.9</Length>
		<Width>4.64</Width>
	</Node>
	<Node exists="Yes">
		<Name>R3</Name>
		<Ref>3</Ref>
		<Length>4.15</Length>
		<Width>4.64</Width>
	</Node>
	<Node exists="Yes">
		<Name>R4</Name>
		<Ref>4</Ref>
		<Length>3.5</Length>
		<Width>4.2</Width>
	</Node>
	<Node exists="Yes">
		<Name>R5</Name>
		<Ref>5</Ref>
		<Length>6.15</Length>
		<Width>5.69</Width>
	</Node>
	<Node exists="Yes">
		<Name>R6</Name>
		<Ref>6</Ref>
		<Length>5.3</Length>
		<Width>2.93</Width>
	</Node>
	<Node exists="Yes">
		<Name>R7</Name>
		<Ref>7</Ref>
		<Length>6.37</Length>
		<Width>4.49</Width>
	</Node>
	<Node exists="Yes">
		<Name>R8</Name>
		<Ref>8</Ref>
		<Length>4.49</Length>
		<Width>3.84</Width>
	</Node>
	<Node exists="Yes">
		<Name>R9</Name>
		<Ref>9</Ref>
		<Length>4.49</Length>
		<Width>3.33</Width>
	</Node>
	<Node exists="Yes">
		<Name>R10</Name>
		<Ref>10</Ref>
		<Length>8.06</Length>
		<Width>4.64</Width>
	</Node>
	<Node exists="Yes">
		<Name>R11</Name>
		<Ref>11</Ref>
		<Length>5.94</Length>
		<Width>3.91</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor1</Name>
		<Ref>12</Ref>
		<Length>7.12</Length>
		<Width>1.18</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor2</Name>
		<Ref>13</Ref>
		<Length>4.11</Length>
		<Width>1.61</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor3</Name>
		<Ref>14</Ref>
		<Length>2.88</Length>
		<Width>1.61</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor4</Name>
		<Ref>15</Ref>
		<Length>3.96</Length>
		<Width>1.61</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor5</Name>
		<Ref>16</Ref>
		<Length>4.48</Length>
		<Width>1.61</Width>
	</Node>
	<Node exists="Yes">
		<Name>Corridor6</Name>
		<Ref>17</Ref>
		<Length>4.6</Length>
		<Width>1.82</Width>
	</Node>
	<Node exists="Yes">
		<Name>Stairs</Name>
		<Ref>18</Ref>
		<Width>1.03</Width>
		<Length>10.89</Length>
	</Node>

	<Connection exists="Yes">
		<Name>Route_1</Name>
		<NodeRef>1</NodeRef>
		<NodeRef>12</NodeRef>
		<Length>8.33</Length>
		<ConnectionType type="Door">
```

```
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_2</Name>
		<NodeRef>2</NodeRef>
		<NodeRef>12</NodeRef>
		<Length>7.44</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_3</Name>
		<NodeRef>3</NodeRef>
		<NodeRef>12</NodeRef>
		<Length>13</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_4</Name>
		<NodeRef>4</NodeRef>
		<NodeRef>13</NodeRef>
		<Length>5.2</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_5</Name>
		<NodeRef>5</NodeRef>
		<NodeRef>13</NodeRef>
		<Length>10.5</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_6</Name>
		<NodeRef>6</NodeRef>
		<NodeRef>14</NodeRef>
		<Length>8.2</Length>
		<ConnectionType type="Door">
			<Width>1.0</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_7</Name>
		<NodeRef>7</NodeRef>
		<NodeRef>15</NodeRef>
		<Length>9.5</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_8</Name>
		<NodeRef>8</NodeRef>
		<NodeRef>16</NodeRef>
		<Length>8.5</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_9</Name>
		<NodeRef>9</NodeRef>
		<NodeRef>16</NodeRef>
		<Length>6.04</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_10</Name>
		<NodeRef>10</NodeRef>
		<NodeRef>16</NodeRef>
		<Length>9.2</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_11</Name>
		<NodeRef>11</NodeRef>
		<NodeRef>17</NodeRef>
		<Length>7.0</Length>
		<ConnectionType type="Door">
			<Width>0.79</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_12</Name>
		<NodeRef>12</NodeRef>
		<NodeRef>13</NodeRef>
		<Length>7.12</Length>
		<ConnectionType type="Door">
			<Width>1.18</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_13</Name>
		<NodeRef>13</NodeRef>
		<NodeRef>14</NodeRef>
		<Length>4.11</Length>
		<ConnectionType type="Door">
			<Width>1.61</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_14</Name>
		<NodeRef>14</NodeRef>
		<NodeRef>15</NodeRef>
		<Length>2.88</Length>
		<ConnectionType type="Door">
			<Width>1.61</Width>
		</ConnectionType>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_15</Name>
		<NodeRef>15</NodeRef>
		<NodeRef>16</NodeRef>
		<Length>3.96</Length>
		<ConnectionType type="Door">
```

```
				<Width>1.61</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_16</Name>
			<NodeRef>16</NodeRef>
			<NodeRef>17</NodeRef>
			<Length>4.48</Length>
			<ConnectionType type="Door">
				<Width>0.79</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_17</Name>
			<NodeRef>17</NodeRef>
			<NodeRef>18</NodeRef>
			<Length>4.6</Length>
			<ConnectionType type="Door">
				<Width>1.03</Width>
			</ConnectionType>
		</Connection>


		<!-- Ground floor "J" -->
		<Node exists="Yes">
			<Name>MeetingRoom</Name>
			<Ref>19</Ref>
			<Length>11.97</Length>
			<Width>6.07</Width>
		</Node>
		<Node exists="Yes">
			<Name>Reception</Name>
			<Ref>20</Ref>
			<Length>12.7</Length>
			<Width>5.06</Width>
		</Node>
		<Node exists="Yes">
			<Name>Corridor</Name>
			<Ref>21</Ref>
			<Length>4.95</Length>
			<Width>3.9</Width>
		</Node>
		<Node exists="Yes">
			<Name>Exit 1</Name>
			<Ref>22</Ref>
			<NodeType>Safe</NodeType>
		</Node>
		<Connection exists="Yes">
			<Name>Route_18</Name>
			<NodeRef>19</NodeRef>
			<NodeRef>20</NodeRef>
			<Length>13.26</Length>
			<ConnectionType type="Door">
				<Width>0.90</Width>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_19</Name>
			<NodeRef>20</NodeRef>
			<NodeRef>21</NodeRef>
			<Length>15.0</Length>
			<ConnectionType type="Door">
				<Width>5.0</Width>
			</ConnectionType>

		</Connection>
		<Connection exists="Yes">
			<Name>Route_20</Name>
			<NodeRef>18</NodeRef>
			<NodeRef>21</NodeRef>
			<Length>10.89</Length>
			<ConnectionType type="Door">
				<Width>1.03</Width>
			</ConnectionType>
			<ConnectionType type="Stairs">
				<Tread>0.28</Tread>
				<Riser>0.18</Riser>
			</ConnectionType>
		</Connection>
		<Connection exists="Yes">
			<Name>Route_21</Name>
			<NodeRef>21</NodeRef>
			<NodeRef>22</NodeRef>
			<Length>4.5</Length>
			<ConnectionType type="Door">
				<Width>1.6</Width>
			</ConnectionType>
		</Connection>
	</EvacuatioNZ_Map>
```


(b) POPULATE file


```
<EvacuatioNZ_Populate version="1.01">
	<Definition>
		<People>1</People>
		<Log>no</Log>
		<Node type="single">1</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>2</People>
		<Log>no</Log>
		<Node type="single">2</Node>
		<PersonType>
			<Name>Normal</Name>
			<Probability>100</Probability>
		</PersonType>
	</Definition>
	<Definition>
		<People>3</People>
		<Log>no</Log>
		<Node type="single">3</Node>
		<PersonType>
```

```
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>1</People>
			<Log>no</Log>
			<Node type="single">4</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>3</People>
			<Log>no</Log>
			<Node type="single">5</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>3</People>
			<Log>no</Log>
			<Node type="single">6</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>2</People>
			<Log>no</Log>
			<Node type="single">7</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>2</People>
			<Log>no</Log>
			<Node type="single">8</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>2</People>
			<Log>no</Log>
			<Node type="single">9</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>4</People>
			<Log>no</Log>
			<Node type="single">10</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>3</People>
			<Log>no</Log>
			<Node type="single">11</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
		<Definition>
			<People>2</People>
			<Log>no</Log>
			<Node type="single">20</Node>
			<PersonType>
				<Name>Normal</Name>
				<Probability>100</Probability>
			</PersonType>
		</Definition>
	</EvacuatioNZ_Populate>
```


(c) SIMULATION file


```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint (University of Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>2.00</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```

(d) SCENARIO file

```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>500</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```

(e) PERSON TYPE file

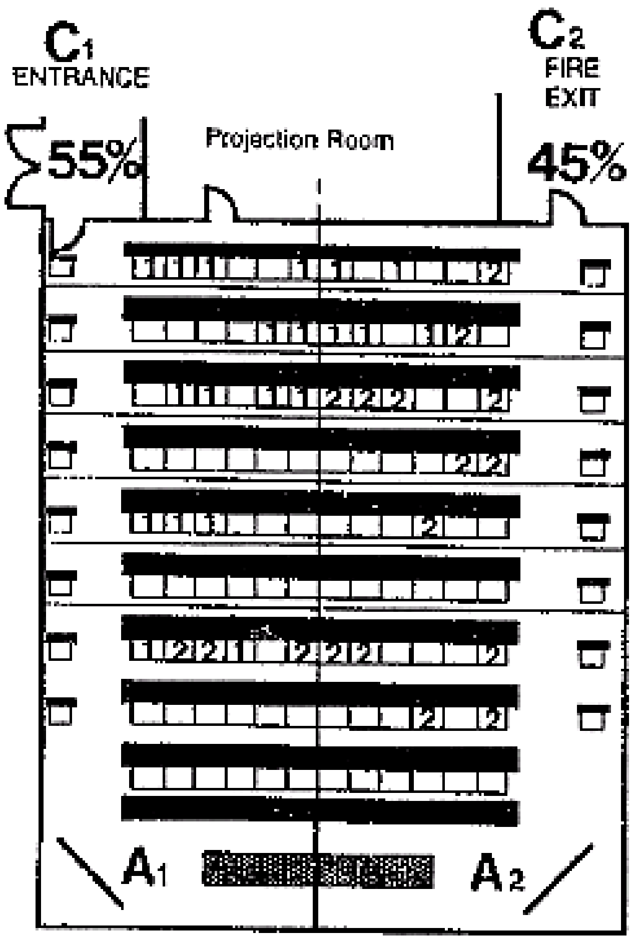
```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default</ExitBehaviour>
	</PersonType>
</EvacuatioNZ_PersonType>
```

(f) EXIT BEHAVIOUR file

```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default">
		<ExitBehaviourType type="MinDistanceToSafe">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```

APPENDIX D: EvacuatioNZ input files for the lecture theatre evacuation simulation

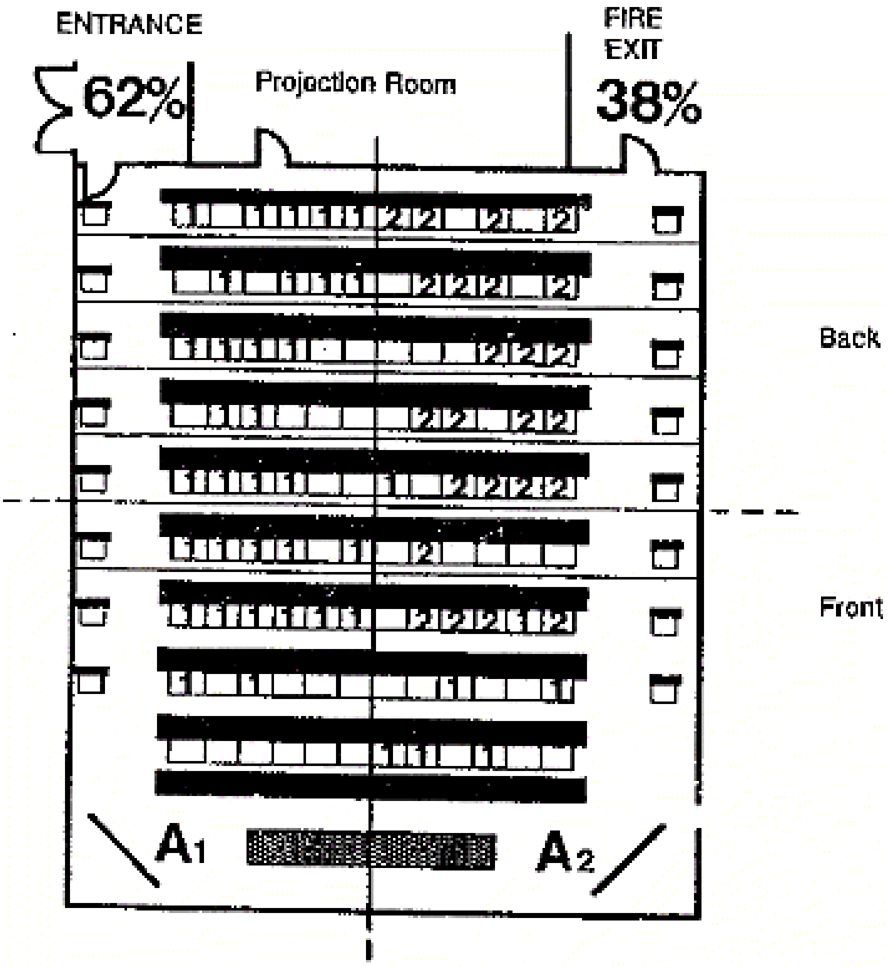
Diagram of Study 1(Sime, 1992):



Code 1 = Used Entrance
Code 2 = Used Fire Exit
(Ent = 0.8m, F Exit - 0.76m wide)

Scale: 1in - 8ft 1in 1cm = 0.97m

Diagram of Study 2 (Sime, 1992):



Code 1 = Used Entrance
Code 2 = Used Fire Exit

Scale: 1 in = 8 ft 1 in
1 cm = 0.97m

An example of EvacuatioNZ input files (Scenario 3 of the lecturer theatre evacuation simulation)

(a) MAP file


```xml
<EvacuatioNZ_Map version="1.01">
        <Description>Lecture Theatre</Description>
        <Node exists="Yes">
                <Name>Lecturer row</Name>
                <Ref>1</Ref>
                <Length>6</Length>
                <Width>0.8</Width>
        </Node>
        <Node exists="Yes">
                <Name>1st row</Name>
                <Ref>2</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>2nd row</Name>
                <Ref>3</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>3rd row</Name>
                <Ref>4</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>4th row</Name>
                <Ref>5</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>5th row</Name>
                <Ref>6</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>6th row</Name>
                <Ref>7</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>7th row</Name>
                <Ref>8</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>8th row</Name>
                <Ref>9</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>9th row</Name>
                <Ref>10</Ref>
                <Length>6</Length>
                <Width>0.60</Width>
        </Node>
        <Node exists="Yes">
                <Name>E1</Name>
                <Ref>11</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E2</Name>
                <Ref>12</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E3</Name>
                <Ref>13</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E4</Name>
                <Ref>14</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E5</Name>
                <Ref>15</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E6</Name>
                <Ref>16</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E7</Name>
                <Ref>17</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E8</Name>
                <Ref>18</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
        <Node exists="Yes">
                <Name>E9</Name>
                <Ref>19</Ref>
                <Length>0.87</Length>
                <Width>0.85</Width>
        </Node>
```

```
<Node exists="Yes">
	<Name>E10</Name>
	<Ref>20</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>

<Node exists="Yes">
	<Name>F1</Name>
	<Ref>21</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F2</Name>
	<Ref>22</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F3</Name>
	<Ref>23</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F4</Name>
	<Ref>24</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F5</Name>
	<Ref>25</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F6</Name>
	<Ref>26</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F7</Name>
	<Ref>27</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F8</Name>
	<Ref>28</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F9</Name>
	<Ref>29</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>F10</Name>
	<Ref>30</Ref>
	<Length>0.87</Length>
	<Width>0.85</Width>
</Node>
<Node exists="Yes">
	<Name>Entrance</Name>
	<Ref>31</Ref>
	<NodeType>Safe</NodeType>
</Node>
<Node exists="Yes">
	<Name>Fire Exit</Name>
	<Ref>32</Ref>
	<NodeType>Safe</NodeType>
</Node>
<Connection exists="Yes">
	<Name>Route_1</Name>
	<NodeRef>1</NodeRef>
	<NodeRef>11</NodeRef>
	<Length>6</Length>
	<ConnectionType type="Door">
		<Width>0.8</Width>
	</ConnectionType>
	<ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
	<Name>Route_2</Name>
	<NodeRef>2</NodeRef>
	<NodeRef>12</NodeRef>
	<Length>6</Length>
	<ConnectionType type="Door">
		<Width>0.6</Width>
	</ConnectionType>
	<ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
	<Name>Route_3</Name>
	<NodeRef>3</NodeRef>
	<NodeRef>13</NodeRef>
	<Length>6</Length>
	<ConnectionType type="Door">
		<Width>0.6</Width>
	</ConnectionType>
	<ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
	<Name>Route_4</Name>
	<NodeRef>4</NodeRef>
	<NodeRef>14</NodeRef>
	<Length>6</Length>
	<ConnectionType type="Door">
		<Width>0.6</Width>
	</ConnectionType>
	<ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
	<Name>Route_5</Name>
	<NodeRef>5</NodeRef>
	<NodeRef>15</NodeRef>
	<Length>6</Length>
	<ConnectionType type="Door">
		<Width>0.6</Width>
	</ConnectionType>
	<ConnectionChoice type="Preferred"/>
```

```
</Connection>
<Connection exists="Yes">
        <Name>Route_6</Name>
        <NodeRef>6</NodeRef>
        <NodeRef>16</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_7</Name>
        <NodeRef>7</NodeRef>
        <NodeRef>17</NodeRef>
        <Length>7</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_8</Name>
        <NodeRef>8</NodeRef>
        <NodeRef>18</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_9</Name>
        <NodeRef>9</NodeRef>
        <NodeRef>19</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_10</Name>
        <NodeRef>10</NodeRef>
        <NodeRef>20</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_11</Name>
        <NodeRef>1</NodeRef>
        <NodeRef>21</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_12</Name>
        <NodeRef>2</NodeRef>
        <NodeRef>22</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_13</Name>
        <NodeRef>3</NodeRef>
        <NodeRef>23</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_14</Name>
        <NodeRef>4</NodeRef>
        <NodeRef>24</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_15</Name>
        <NodeRef>5</NodeRef>
        <NodeRef>25</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_16</Name>
        <NodeRef>6</NodeRef>
        <NodeRef>26</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_17</Name>
        <NodeRef>7</NodeRef>
        <NodeRef>27</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
                <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_18</Name>
        <NodeRef>8</NodeRef>
        <NodeRef>28</NodeRef>
        <Length>6</Length>
```

```
        <ConnectionType type="Door">
            <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_19</Name>
        <NodeRef>9</NodeRef>
        <NodeRef>29</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
            <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_20</Name>
        <NodeRef>10</NodeRef>
        <NodeRef>30</NodeRef>
        <Length>6</Length>
        <ConnectionType type="Door">
            <Width>0.6</Width>
        </ConnectionType>
        <ConnectionChoice type="ExitSign"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_21</Name>
        <NodeRef>11</NodeRef>
        <NodeRef>12</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_22</Name>
        <NodeRef>12</NodeRef>
        <NodeRef>13</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_23</Name>
        <NodeRef>13</NodeRef>
        <NodeRef>14</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_24</Name>
        <NodeRef>14</NodeRef>
        <NodeRef>15</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_25</Name>
        <NodeRef>15</NodeRef>
        <NodeRef>16</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_26</Name>
        <NodeRef>16</NodeRef>
        <NodeRef>17</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_27</Name>
        <NodeRef>17</NodeRef>
        <NodeRef>18</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_28</Name>
        <NodeRef>18</NodeRef>
        <NodeRef>19</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_29</Name>
        <NodeRef>19</NodeRef>
        <NodeRef>20</NodeRef>
        <Length>0.87</Length>
        <ConnectionType type="Door">
            <Width>0.85</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
        <Name>Route_30</Name>
        <NodeRef>20</NodeRef>
        <NodeRef>31</NodeRef>
        <Length>1</Length>
        <ConnectionType type="Door">
            <Width>0.8</Width>
        </ConnectionType>
        <ConnectionChoice type="Preferred"/>
</Connection>
<Connection exists="Yes">
```

```
		<Name>Route_31</Name>
		<NodeRef>21</NodeRef>
		<NodeRef>22</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_32</Name>
		<NodeRef>22</NodeRef>
		<NodeRef>23</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_33</Name>
		<NodeRef>23</NodeRef>
		<NodeRef>24</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_34</Name>
		<NodeRef>24</NodeRef>
		<NodeRef>25</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_35</Name>
		<NodeRef>25</NodeRef>
		<NodeRef>26</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_36</Name>
		<NodeRef>26</NodeRef>
		<NodeRef>27</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_37</Name>
		<NodeRef>27</NodeRef>
		<NodeRef>28</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_38</Name>
		<NodeRef>28</NodeRef>
		<NodeRef>29</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_39</Name>
		<NodeRef>29</NodeRef>
		<NodeRef>30</NodeRef>
		<Length>0.87</Length>
		<ConnectionType type="Door">
			<Width>0.85</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>
	<Connection exists="Yes">
		<Name>Route_40</Name>
		<NodeRef>30</NodeRef>
		<NodeRef>32</NodeRef>
		<Length>1</Length>
		<ConnectionType type="Door">
			<Width>0.76</Width>
		</ConnectionType>
		<ConnectionChoice type="ExitSign"/>
	</Connection>

</EvacuatioNZ_Map>
```

(b) POPULATE file


```xml
<EvacuatioNZ_Populate version="1.01">
    <!-- Population in "F theatre" -->

    <Definition>
        <People>3</People>
        <Log>no</Log>
        <Node type="single">3</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>9</People>
        <Log>no</Log>
        <Node type="single">4</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>5</People>
        <Log>no</Log>
        <Node type="single">5</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>5</People>
        <Log>no</Log>
        <Node type="single">6</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>5</People>
        <Log>no</Log>
        <Node type="single">7</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>10</People>
        <Log>no</Log>
        <Node type="single">8</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>10</People>
        <Log>no</Log>
        <Node type="single">9</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
    <Definition>
        <People>9</People>
        <Log>no</Log>
        <Node type="single">10</Node>
        <PersonType>
            <Name>Normal1</Name>
            <Probability>55</Probability>
        </PersonType>
        <PersonType>
            <Name>Normal2</Name>
            <Probability>45</Probability>
        </PersonType>
    </Definition>
</EvacuatioNZ_Populate>
```

(c) SIMULATION file


```
<!-- edited with XML Spy v3.5 beta 1 build Nov 10 2000 (http://www.xmlspy.com) by Mike Spearpoint (University of
Canterbury) -->
<EvacuatioNZ_Simulation version="1.01">
	<TimeMax>12000</TimeMax>
	<TimeStep>1</TimeStep>
	<MaxNodeDensity>3</MaxNodeDensity>
	<DoorFlow>Maclennan</DoorFlow>
	<OccupantDensityModel localOccupantDensity="3.0">mixed</OccupantDensityModel>
</EvacuatioNZ_Simulation>
```


(d) SCENARIO file


```
<EvacuatioNZ_Scenario version="1.01">
	<Simulations>500</Simulations>
	<DumpEvacuationTimes>Yes</DumpEvacuationTimes>
	<RandomStartPosition>Yes</RandomStartPosition>
	<Files>
		<Simulation>simulation.xml</Simulation>
		<PostProcess>pp template.xml</PostProcess>
		<Populate>populate.xml</Populate>
	</Files>
</EvacuatioNZ_Scenario>
```


(e) PERSON TYPE file


```
<EvacuatioNZ_PersonType version="1.01">
	<PersonType name="Normal1">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default1</ExitBehaviour>
		<PreEvacuation type="distribution">
			<Distribution type="normal">
				<Mean>45</Mean>
				<StandardDeviation>5</StandardDeviation>
			</Distribution>
		</PreEvacuation>
	</PersonType>
	<PersonType name="Normal2">
		<Speed>1.20</Speed>
		<ExitBehaviour>Default2</ExitBehaviour>
		<PreEvacuation type="distribution">
			<Distribution type="normal">
				<Mean>90</Mean>
				<StandardDeviation>5</StandardDeviation>
			</Distribution>
		</PreEvacuation>
	</PersonType>
</EvacuatioNZ_PersonType>
```


(f) EXIT BEHAVIOUR file


```
<EvacuatioNZ_ExitBehaviour version="1.01">
	<ExitBehaviour name="Default1">
		<ExitBehaviourType type="Preferred">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
	<ExitBehaviour name="Default2">
		<ExitBehaviourType type="ExitSign">
			<Probability>100</Probability>
		</ExitBehaviourType>
	</ExitBehaviour>
</EvacuatioNZ_ExitBehaviour>
```