UNIVERSITY OF NAIROBI

School of Computing and Informatics

A MULTIAGENT SYSTEM BASED SAFE FIRE EMERGENCY EVACUATION GUIDE:
(A SIMULATION FOR A MODERN OFFICE BUILDING IN KENYA)

BY

KEVIN MUGOYE SINDU

A Research Proposal Submitted to the Department of Computer Science, School of Computing and Informatics for the Partial Fulfillment of the Degree of Master of Computer Science.

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DECLARATION

This project proposal is my original work and has not been presented for a degree in any other university or for any other award.

Student:

Signature: Date: 27th, November 2012

Kevin Mugoye Sindu

Registration Number: P58/62051/2010

Supervisor:

I declare that this project has been presented with my approval as the supervisor

Signature: ______ Date: 3/12/ 2012

Dr. Elisha T. Opiyo Omulo

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Last but not least, the omnipresent God, who has been the enabler.

Abstract

Evacuation of people in the event of hazard is one of basic problems of human society. In emergency scenarios there is limited time to act and or react; this results to extensive life loss because the time needed for safe evacuation in a threatened building was not available, or people running to the wrong direction of safety. In pursuit for a solution, systems have been developed to alert or warn occupants on the presence of a fire emergency so that they can act on time. Despite having such systems in place, efficiency in evacuation has not been realized, a fact that has opened room for more research and study. Studies indicate that a substantial number of deaths occur due to wrong decisions occupants make within the available evacuation time. Besides, they reveal that guiding occupants during evacuation proves to be more effective because it decreases the average escape time thereby increasing the chance of survival in fire emergency situation (Fahy & Proulx 2009). In Kenya, building management and building owners use the evacuation plans designed to them to aid evacuation during fire emergencies. In evacuation the plans are limited in that they do not explicitly tell you how but what to do. We propose to do a simulation of safe emergency evacuation guide (EvacSim) with the intention of determining evacuation efficiency. The simulation intends to highlight building fire disaster and how to achieve efficiency in evacuation. Efficiency translates to more lives saved within a short period of time. At extreme cases were available exits are blocked the simulation will show a location of safety as occupants await external assistance. EvacSim can be furthered to produce a system for similar purpose; Full adoption of the system will realize a good number of people being evacuated within a short time; As a result, there will be an increase in the number of evacuees safely evacuated while a decrease in the number of fatalities.

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1. ABMS:- Agent Based Modeling and Simulation
2. AI:- artificial intelligence
3. CWT:- Cumulative wait time
4. DAI:-distributed artificial intelligence
5. EvacSim:- safe emergency evacuation guide simulation
6. JADE:-Java Agent Development Framework, is a software Framework fully implemented in Java language.
7. MAS :- Multi agent System
8. MaSFEEG:- multi-agent system based safe fire emergency evacuation guide
9. NFA :- National Fire Academy
10. NIST:- National Institute of Standards and Technology
11. OO:- Object Oriented
12. PET: - Personal Evacuation Time

1. CHAPTER ONE: Introduction

1.1 Background to the study

Defining Modernism and Modern architectural design is a contentious issue that is subject to continual debate by architects, planners and architectural historians. Even the validity of classifying buildings into styles is a subject under debate within the academic community. This context statement recognizes the limitations of classification and does not attempt to resolve this ongoing debate; rather, a set of working definitions was developed in order to aid the understanding of Modern design. There are numerous ongoing debates concerning the use of the terms Modern, Modernism, and the Modern Movement. These terms have been used to describe periods of time as well as aesthetic stylistic design vocabularies. In some cases the term modern is used to describe contemporary architecture. The Modern Movement in the United States is described as a period of innovative design, begun at the turn of the century, led by luminaries such as Louis Sullivan and Frank Lloyd Wright. European Modernism is often described as a 1910s-30s-era architectural movement led by Le Corbusier, J.J.P. Oud, Peter Behrens, and inclusive of the Bauhaus movement led by Walter Gropius and Ludwig Mies van der Rohe. For the purpose of this context statement, the terms Modern and Modernism will refer to a style and design. In this context statement, the terms Modern and Modernism are used broadly to describe a variety of architectural styles. Style and design in the United States spanned from the late 1920s through the 1960s, with Key characteristics of Modern buildings including the absence of historical ornament and references, and the use of new technologies, materials and construction techniques.

There is consensus by many scholars that modern building in Africa incorporates modern architecture which tries to reconcile the principles underlying architectural design with rapid technological advancement and the modernization of society. This buildings have fitting of security systems and devices (e.g., closed-circuit TV cameras), fire alarm systems which have evolved from being manually actuated to being automatic actuated. In Kenya, the term modern in the construction industry refers to the era ranging from the 90s to current; therefore office buildings constructed within this period can be considered to be modern office buildings. Indeed, this era has witnessed a major expansion of skyscrapers and high-rise buildings; with a majority being office towers located in Nairobi. According to skyscrappers.com, these buildings include lonhro house, anniversary towers, rahimtulla tower, I&M bank tower, telleposta towers and new central bank tower (times tower) as indicated in Table 7.

Though this project intends to develop a simulation of an emergency evacuation guide useful to modern buildings, the simulation can be furthered to full realization of the system. The simulation intends to determine the efficiency of guiding or directing evacuees during emergency evacuation in a building. The simulation tends to show an area or areas of danger in a building during a fire emergency and makes use of intelligent agents to provide the best possible directions to area of safety, normally the building exit. The goal of the system is to aid evacuate an optimum number of people in an office building in the event of fire emergency within a limited period of time. The fundamental concerns that will enable the realization of this objective include: (1) Identifying the source of danger, (2) simulating movement from source of danger, and (3) determining directions to the nearest safe exit.

1.2 Problem statement

There exists no defined cause of building fires as the list may be endless, from electrical faults, careless handling of equipments, chemical reactions, human error etc; therefore building fires cannot be eliminated in totality, but can be prevented. The hazards caused by building fires are numerous, in worst cases death occur. The most significant cause of death in building fires is smoke, which accounted for 73% of fire-related deaths in 1990, according to a 1994 report by the National Fire Protection Association. However, fires also can cause structural collapse of buildings, and burns cause the remainder of deaths in fire. To reduce fire-related deaths, a number of measures have been taken and research conducted on the same. A lot of developments and research are aiming at providing more efficient means for alarming and guiding people. Good examples are fire alarming systems.

A majority of modern buildings are currently equipped with modern fire detection systems and it is possible to alert people in the event of fire. However, these systems give no clues as to how to escape in case the alarm goes on. This results to panic and irrational acts from the occupants, making it hard to evacuate the building. Occupants run to dead ends, others run to the area of danger thereby threatening their lives. Safe evacuation process begins with time utilisation and ends with time, the point when the alarm is sounded, the point when the occupants recognize that an emergency situation is taking place, the point when the occupants respond to the situation for starting the escape movement and the point when the occupants start to evacuate to the area of safety should be less than available safe egress time. This does not happen naturally however; by guiding occupants to area of safety it can be achieved (Sime 2001). How do we establish safe areas or areas of safety? Although exit points provide assurance of safety, it is not easy to identify them in emergency situations. Evacuation can be facilitated by a communication system designed to show the area of the building that poses the greatest danger and the areas that poses the least danger to the people.

To suggest a possible solution, systems with some intelligence and have ability to provide directions are preferred and hence the use of artificial intelligence. Since fire emergencies do not happen frequently, and can not be eagerly waited for, showing the necessity of such systems can be a big task. Therefore we propose to show the effectiveness of a fire emergency evacuation guide through a simulation. The simulation may be furthered to the development of the real system.

1.3 The Objective of the study

The aim of this research is to design a computer model or simulation that will give insight in the development of an emergency evacuation system. The simulation aims at determining the evacuation efficiency in directing occupants to safety during a fire emergency within a building. This model is designed to provide directions to safe exits to evacuees during fire emergency evacuation in a modern building. Success in this model will lead to recommendations to develop a system prototype to solve the same problem. To achieve this we intend to do the following;-

1) Formulate a multi-agent system based emergency procedure in modern building.
2) Develop the conceptual model of the multi-agent based emergency evacuation Guide.
3) Build the computer implementation of the conceptual model of the multi-agent based emergency evacuation Guide.
4) Run the simulations using the computer implementation above and collect the test data
5) Analyse the data obtained from the simulation.

1.4 Justification of the study

In emergency situations, panic disorients occupant's judgment or decision making, however, providing cues and or information reduces panic therefore increases the chances of making the right decisions on escape (Fahy & Proulx 2009). Besides, the available security systems cannot be relied upon to support evacuation in the event of fire emergency, the use of security personnel during or to aid evacuation is impractical as they too are humans and prone to human failures, evacuation plans though useful, do not tell "how" but "what" to do during fire emergency evacuation, evacuation plans are rigid and cannot adjust to scenarios , if successful will lead to many lives saved during fire emergency evacuation and reduce fatalities and the study can serve as a basis for further research.

Therefore a solution would be, to support the fire alarm systems with other technologies. One such technology is what I propose; a multi-agent system for safe fire emergency evacuation guide (MaSFEEG). However, one major challenge in this undertaking is that it will be impossible to convince humans of the full benefits of the proposed system; therefore an ideal starting point will be to build a simulation of emergency fire evacuation in a building (EvacSim) using Intelligent entities so that we can determine the evacuation efficiency and value of guiding occupants during fire emergencies in a building. Besides, Perros (2009) asserts that creating a model is ideal since this system does not exist. This simulation (EvacSim) can be furthered to the development of the system prototype of MaSFEEG.

One emphasis of this study is to enable people realise the need to see beyond fire emergencies, see the value of the proposed system and also its limitations. The success of EvacSim will prompt recommendation for the adoption and implementation of MaSFEEG.We were further encouraged by this study from its benefit viewpoint, Adoption of MaSFEEG will realize a number of benefits; first it will lead to reduced fatalities, secondly it will increase the percentage of evacuees safely evacuated and overall it will increase employee confidence in workplaces as far as their safety is concerned. In pursuit of domain expert opinion, Turner (1995) recommended that since fire emergency situations are not static, there is need for systems that adapts to the situations.

1.4.1 Why a simulation

Before considering a simulation, we did compare an alternative which was to build a system. It emerged that many of the pitfalls that are often encountered in the start up of a new system can be avoided by using simulation. In addition simulation will enable one to visualize the operation of a system and clearly demonstrate the ability or inability of the system to meet the performance objectives. Besides, because of the delicate nature and preciousness of human life a high level of accuracy in decision making is required, this can be determined through a simulation. We further strengthened the reason for our choice by considering why simulations are done (Robinson, S 2004). We established that we could achieve the following benefits; (1) Improve the understanding of how a system operates. (2)Lessen the cost associated with experimenting on the real system. (3) Minimize the risk of error when dealing with actual or proposed systems. (4) Provide practical feedback when designing real world systems. Further analysis revealed that simulation permits a hypothetical system to be evaluated when it does not yet exist; Simulation provides an excellent means of communicating ideas by creating a model of the system being studied and lastly simulation provides an educational tool for teaching how the system will operate; simulations are not industry specific i.e. can be applied to any process based environment. Lastly Multi agent systems simulations use virtual time, time and environments are controllable by the modeler. As asserted by Perros (2009) creating a model is ideal since this system does not exist.

1.5 Scope of the project

This project concentrates in office buildings in the continent of Africa and with bias to office buildings in Kenya. The aim is not to replace the available technology but to compliment it for better performance. The project will cover one floor in a high-rise building and not the entire building.

1.6 Limitations

1. The model will not be sufficient for natural calamities such as earthquake and floods.
2. The simulation is appropriate for modern buildings installed with automatic fire alarm system
3. Inappropriate simulation software.
4. Unavailability of data from similar research.
5. There exits vital information in artificial intelligence magazines, however magazines are not generally considered scholarly pieces of work for research.

1.7 Assumptions

1. The project team will fully commit themselves to the project from inception to end.
2. The building has a building plan or layout
3. Building exits have a standard width
4. Building has more than one exit
5. Security officers cannot override a decision from the system.
6. Everybody has an objective of staying alive.
7. A majority of the building occupants use computers.
8. A majority of the building occupants are familiar to the building
9. Since floor plans are identical the simulation covers one floor.

1.8 The definitions of terms

1. AnyLogic:-a commercial simulation software from XJ technologies in the domain of MAS.
2. CWT (cumulative wait time):- a measure of the total amount of time that a person wastes in indecision or wrong choice of exit
3. Evacuees: - people who need to be evacuated from a building.
4. JADE:-Java Agent Development Framework, is a software Framework fully implemented in Java language.
5. Jason: - A Java-based interpreter for an extended version of AgentSpeak language (a platform).
6. Optimum: - maximum possible using the minimal resources available.
7. PET (personal evacuation time): - a measure of the time each individual requires to evacuate.

1.9 Chapter Summary

This chapter creates understanding to modern as will be used in the research, highlighting examples of buildings that qualify to be called modern in Kenya. We define the problem that leads to the research problem and suggest possible solution. We delineate the objectives of our research and defend the approach taken to provide solution. We recognize the scope, limitations assumptions and define important terminologies used in our research.

2. CHAPTER TWO: The Literature review

2.1 Theory of Multi agent systems and a brief history

As argued by Bond & Gaser (1995), Distributed Artificial Intelligence is a sub field of A.I. that has existed since the early 1980s. It is normally seen as being composed of two main disciplines. One is known as Distributed Problem Solving, which is concerned with the information management aspects of multiple component systems e.g. task decomposition and solution synthesis. The other is known as Multi-Agent Systems (MAS) and deals with the behaviour management of multiple independent entities or agents that interact in a common environment. Weiss (1999) asserts that an agent is a computational entity such as a software program or a robot that can be viewed as perceiving and acting upon its environment, besides an agent is autonomous in that its behavior at least partially depends on its own experience. Weiss (1999) insists that distributed artificial intelligence (DAI) is a subfield of artificial intelligence research dedicated to the development of distributed solutions for complex problems regarded as requiring intelligence. DAI is closely related to and is a predecessor of the field of Multi-Agent Systems.

Lesser (1999) affirms that Multi-agent systems are computational systems in which more than one agents work together to perform some set of tasks or to satisfy some set of goals. He considers an agent in a system as a locus of problem-solving activity, which operates asynchronously with respect to other agents and has some level of autonomy. Wooldridge (2009) describes Multi-agent systems as a new paradigm for understanding and building distributed systems, where it is assumed that the computational components are autonomous and able to control their own behaviour in the furtherance of their own goals. In describing the behaviour of an agent, he maintains that an agent should operate flexibly and rationally in a variety of environmental circumstances given its perceptual and effectual equipment. This Behavioral flexibility and rationality are achieved by an agent on the basis of key processes such as problem solving, planning, and decision making, and learning (Weiss 1999). Weiss (1999) further argues that the increasing complexity of computer and information systems goes jointly with increasing complexity of their applications. He describes this as a problem that surpasses the level of conventional, centralized computing and proposes that a solution can be achieved by allowing computers to act more as agents, rather than just "parts". Research conducted on Multi-agent systems has tried to provide principles for the construction of complex systems involving multiple agents and the mechanisms required for coordinating agents' behaviour.

2.2 The rationale for incorporating Multi-Agent Systems

We settled for agent-oriented approach to development of the model for some obvious reasons. We analysed some of the benefits which included (1) agent oriented decompositions are an effective way of partitioning the problem space of a complex system; (2) the key abstractions of the agent-oriented mindset are a natural means of modeling complex systems. Besides results from studies reveal that, it is apparent that the natural way to modularize a complex system is in terms of multiple autonomous components that can act and interact in flexible ways in order to achieve their set objectives. Our choice was further boosted by examining the capabilities of MAS (Sycara 1998).

We evaluated other approaches, such as object-oriented approach and established that it is less suitable for this kind of problem because OO approach cannot naturally represent the autonomous problem-solving behaviour of the constituent components and it has no innate mechanism for representing and reasoning (Faratin et al. 2000). In addition other approach such as using decision and communication nodes proved to be very costly. Besides, the development of agent modeling tools, the availability of micro-data, and advances in computation have made possible a growing number of agent-based applications across a variety of domains and disciplines (Macal and North 2010). With all this facts at hand, the multi-agent approach is simply the best fit to for this study.

2.3 Computer Simulation from the viewpoint of its benefits

In general, a simulation refers to a computerized version of the model which is run over time to study the implications of the defined interactions. Simulations are generally iterative in their development. Discussing simulation from the point of view of its benefits, it is clear that they are able to provide users with practical feedback when designing real world systems (Robinson, S 2004). This allows the designer to determine the correctness and efficiency of a design before the system is actually constructed. Besides, the overall cost of building the system diminishes significantly since the effects of specific design decisions is investigated during the design phase rather than the construction phase. Lastly simulators permit system designers to study a problem at several different levels of abstraction. By approaching a system at a higher level of abstraction, the designer is better able to understand the behaviors and interactions of all the high level components within the system and is therefore better equipped to counteract the complexity of the overall system.

Since this model deals with emergency and the involvement of human life, it demands high accuracy of prediction, simulation is viewed as an ideal technique. An accurate simulation model would allow the responsible agencies to evaluate a good evacuation scheme. Previous studies indicate that in order to obtain a perfect evacuation efficiency, a number of factors need to be considered (Shen & Chien 2005), such factors include, the building configuration layout (i.e. number of exits, exit width, travel distance), occupant's familiarity of the building, etc. A number of simulation models have been designed to represent behaviour and movement in evacuation and simulate path selection; Gwynne & Galea (2004) highlights examples of such models to include EGRESS, E-ESCAPE, EVACSIM, etc.

2.4 Multi agent systems and Simulation

Agent-based modeling is a way to model the dynamics of complex systems and complex adaptive systems. Such systems often self-organize themselves and create emergent order. Agent-based models also include models of behaviour (human or otherwise) and are used to observe the collective effects of agent behaviors and interactions. According to a paper presented by Almeida et al. (2008), multi agent systems approach is seen as ideal for modeling fire evacuation in a building since it allows modeling of each individual person with their unique characteristics, thus creating the real world interaction among human beings. This was supported by Nguyen et al. (2005), Musse & Thalmann (2001) and Pan et al. (2005), who consider Agent-based simulation as an ideal choice for crowd modeling and simulation as it addresses the issue of scalability. Furthermore Shendarkar et al. (2006), show that it is possible to simulate crowd behaviour in response to an emergency using BDI agents. Considering the use of MAS in simulation SIMULEX was the first application to use multi agent systems (cited in Santos & Aguirre, 2008).

2.5 Assessment of modern buildings

The definition of a modern building varies sharply depending on where it's used, however it is clear that a building constructed in the modern period qualifies to be a modern building. In the USA for instance a modern period is the duration ranging roughly from the 1920s to the 1970, whereas in Africa continent this may not be the case. Modern building incorporates modern architecture; modern architecture is generally characterized by simplification of form and creation of ornament from the structure and theme of the building. Modern period is a term applied to an overarching movement, with its exact definition and scope varying widely. (U.S. General Services Administration. 2003) In a broader sense, early modern architecture began at the turn of the 20th century with efforts to reconcile the principles underlying architectural design with rapid technological advancement and the modernization of society.

For the purpose of this context statement, the terms Modern and Modernism will refer to a style and design. We will use them broadly to describe a variety of architectural styles. In Kenya, the modern and Modernism era referred to the era ranging from the 90s to current with

Key characteristics of Modern buildings including the absence of historical ornament and references, and the use of new technologies, materials and construction techniques. In this proposal, modern building has been approached from the Africa continent context and the country Kenya to be precise. Consider how security is addressed in a modern building; first fitting of security systems and devices (e.g., closed-circuit TV cameras), fire alarm systems which have evolved from being manually actuated to being automatic actuated. It is a requirement that Commercial or office buildings be installed with fire protection systems. These systems assist with detection and response to fire related emergencies. The fire alarm is one such system. Fire alarm systems are intended to notify the building occupants to evacuate in the event of a fire or other emergency. An automatic fire alarm system is designed to detect the unwanted presence of fire by monitoring environmental changes.

2.6 Use of Multi-Agent Systems in fire emergency evacuation

The power of ICT has increasingly influenced software development in every field of application from personal computing, to critical infrastructures and industrial systems. Developing a software system involves the challenge of coping with embedded computational complexities of distribution, multi-tasking, and real-time. Moreover, it is nearly impossible for users to manually command/control a software system that is even mildly complex. Clearly, the need for sophisticated, automatic intelligence must be brought into the life cycle and development environment. Accordingly, agent-oriented computing, which provides such intelligence, has become an important research topic.

In trying to understand how to improve evacuation MAS has been used to model fire emergency and simulate human behaviour during fire emergencies (Fahy & Proulx 2009).Since commercial or office buildings are required by construction laws to be installed with fire protection systems; Multi-agent systems has been incorporated in managing building fires by introducing intelligent entities that works jointly with other available technologies to aid in detection and response to fire related emergencies.

2.8 Similar work

The latest achievements in number of various both fundamental and applied disciplines, such as Simulation, software tools and many others, implies that there exist models which are closely related to this in terms of functionality. However, most are based on decision nodes and communication nodes. According to Dimakis & Gelenbe (2010) there exist simulations that models evacuees' behaviour in multi storey building.

2.7 The Gap

A number of studies reveal that in alarm systems, alarm signals alone do not provide sufficient information for occupants to make accurate decisions about whether or not to evacuate immediately. Besides, other study show that peoples response to alarm is poor due to a varying number of reasons (proulx 2000). Conversely, Groner (1998) suggests that it is possible to improve the occupant's response to a fire alarm; this was later justified by NFA (1999). Proulx (1998) and Sime (2001) suggested that one way to make the fire alarm effective is to complement it with other systems.

How do we evacuate the maximum possible number of evacuees in case of emergency within a limited time? In order to answer our big question we need to study human behaviour in the event of such an emergency. In the event of threatening situation, human beings tend to behave in an irrational manner, according to Fahy & Proulx (2009) this behaviour is explained as panic. Besides, every person has her own parameters that influence their behaviour. Of course, the list of factors affecting the movement of a person is nearly endless. However, Jafari & Maher (2003) argue that at the end of the day, the movement of a person from a physical point of view is only characterized by her speed and her direction. You will agree with me that it's difficult to control humans once they exhibit panic. So how do we achieve evacuation efficiency (evacuation of the maximum possible number of building occupants within limited time), having considered all this factors? My take is to bring a solution that will reduce panic and increase confidence; that's why I propose MaSFEEG, to sell the system, we intend to give insight on how the system will work, and that explains the reason for constructing our model (EvacSim).

2.9 Proposed architecture / conceptual model

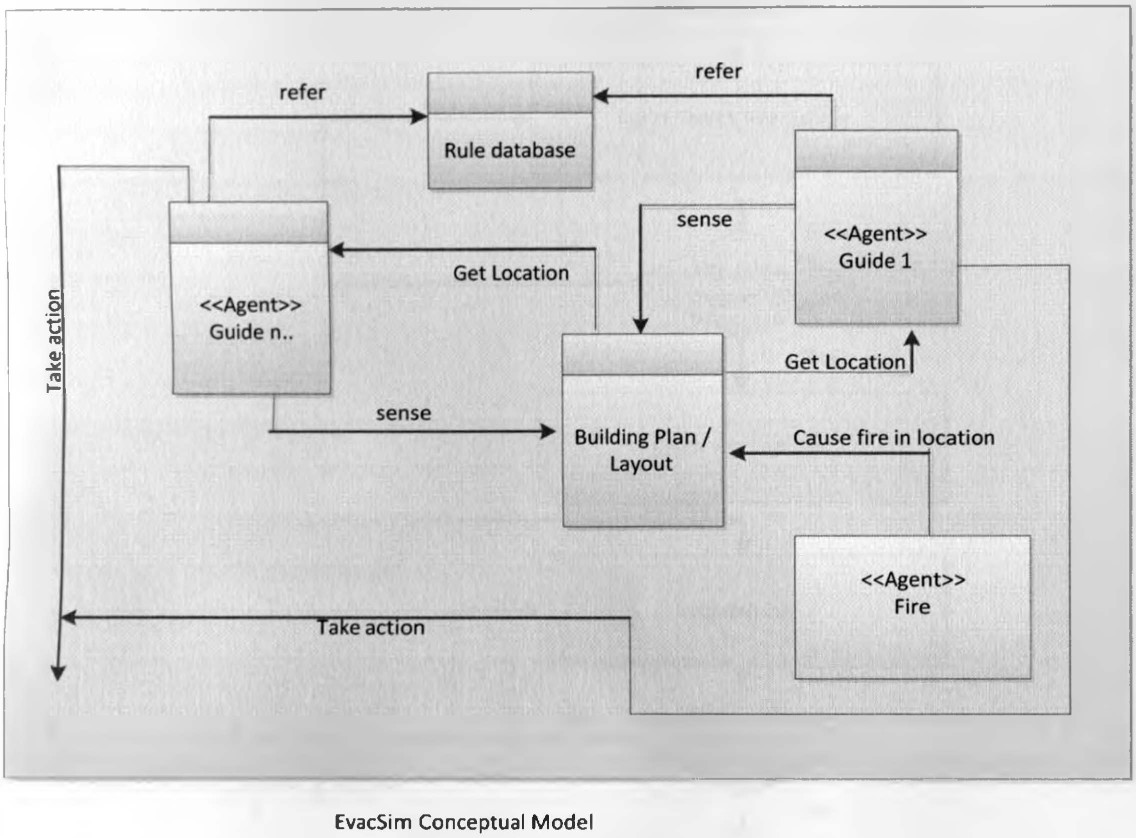


Figure 2-1. *Context diagram.*

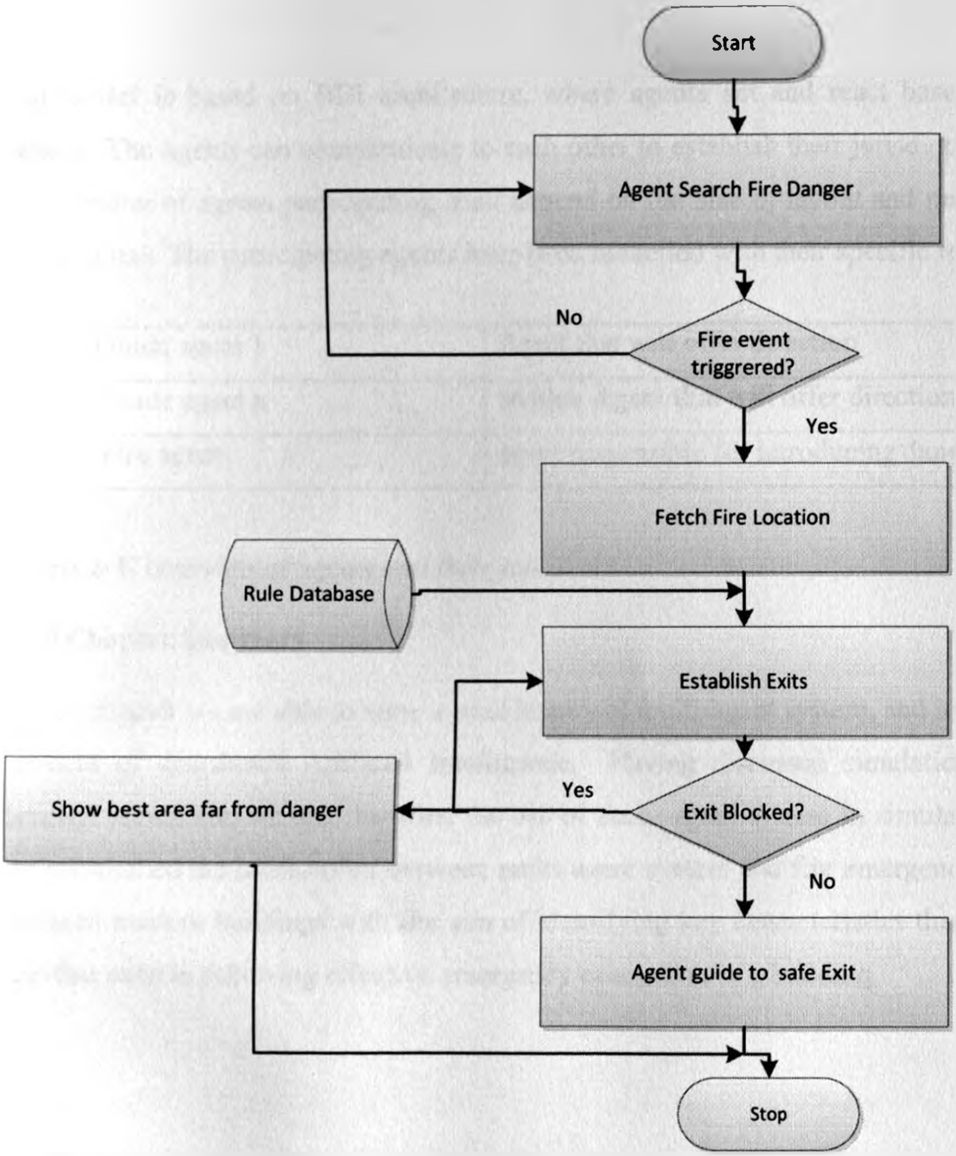


Figure 2-2. *The conceptual model of processes*

The model is based on BDI architecture, where agents act and react based on what they believe. The agents can communicate to each other to establish their jurisdiction or boundary. The number of agents participating shall depend on the size of layout and number of exit the building has. The participating agents have been modelled with their specific roles outlined in

Guide agent 1	Agent that will offer direction
Guide agent n	another Agent that will offer direction
Fire agent	agent responsible for introducing danger

Table 2-1. *Overview of agents and their role*

2.10 Chapter Summary

In this chapter we are able to view a brief history of multi-agent system, and identify MAS as a subfield of distributed Artificial Intelligence. Having discussed simulation and from the benefits viewpoint, we also Justified the use of multi-agent system in simulation. There after we established the relationship between multi-agent system and fire emergency modeling. We assessed modern buildings with the aim of identifying key characteristics then established the gap that exist in achieving effective emergency evacuation in a building.

3. CHAPTER THREE: Methodology

3.1 Overview

The purpose of this chapter is to describe the methodology used in this research. In methodology we provide a step by step instruction for undertaking our study as a way to solve the research problem (Kothari 2004). We have explained the following: - research design, sources of data, methods and tools to be used in data collection and data analysis methods. The methodology is subdivided in various sections as exemplified below.

1. Research design: - this section describes the various designs that will be used in undertaking and developing this project. Such as the problem design, tools design and system design.
2. Tools and skills required:-this section illustrates the tools and skills required for the agent design and implementation.
3. System design;-this section involves designing the agents and showing how the agents will work.
4. Implementation and evaluation;-this section illustrates how to implement the agents, conducting an evaluation of the agents and development environment.

3.2 Research design

The function of a research design is to ensure that the evidence obtained enables us to answer the initial question as unambiguously as possible. Chauhan D (1997) and Kothari C.R. (2004) discuses research design as an arrangement of conditions for collection and analysis of data in a manner that aims to coalesce relevance to the research purpose with economy in procedure. Within the research design we view the problem design; tools design, procedures of data collection and system implementation.

3.2.1 Problem design

The approach of this study begins with a review of previous work done on emergency evacuation. A number of closely related models have been reviewed and their shortcomings highlighted. The model is applied in emergency evacuation scenario to determine the evacuation efficiency during a fire emergency evacuation, an agent or a number of agents will participate in the system though individually to find the way to a safe exit avoiding contact with danger (fire).We will observe (1) getting to safety and (2) time taken get there. Agents need to make decisions aimed at ensuring their safety depending on the situation.

3.2.2 Tool design

We intend to integrate Eclipse Integrated Development Environment, with AnyLogic professional so that we can use java functionalities in building our computer implementation of the conceptual model when needed. In case of financial constraints we may replace AnyLogic professional with Repast Symphony for the same functionality.

3.2.3 Procedure of data collection

In our undertaking our design type will be experiment and method of data collection will be observation. We intend to get Evacuation data from Kenya Fire Brigade (Nairobi) to be used during our result analysis. According to Ferworn (2007), data collection using observation and experimental methods are done mainly to give us original data from the experiments conducted on agent to verify whether it functions as required. The fundamental reason as to why we incorporating this method of data collection is that, it is cheaper, faster and less involving as suggested by Chauhan (1997).

3.2.4 System Implementation

Once we install JVM or JRE for running java, install eclipse and Anylogic and or Repast Simphony IDE, we will run the computer implementation of the conceptual model, while paying attention to what our methodology requires.

3.3 Tool and skills required

- Java Virtual Machine or Java Runtime Environment (Open source)
- Anylogic Software (commercial)
- Repast Software (Open source)
- Eclipse Integrated Development Environment
- Laptop / desktop computer
- Agent Oriented programming skills and reference materials
- Java programming skills and reference materials
- System analysis and design and reference materials

3.4 System design

We focus on designing the agents and showing how the agents will work with attention to what our methodology prescribes. The design covers or spans across the various phases as prescribes by our methodology. This phases include; - System Analysis, Conceptual System modeling, and Simulation Design. In our study we settled for Agent Based Modeling and Simulation (ABMS) methodology.

3.4.1 Why ABMS Methodology

The choice of this methodology was arrived at after considering others methodologies e.g. MaSE methodology by DeLoach (1999) just to mention. It emerged that ABMS offers distinct advantages; most of which fit our research problem. Some of the factors highlighted which determined the suitability of ABMS, include;-(1)When the problem has a natural representation as being comprised of agents,(2)When there are decisions and behaviors that can be well-defined ,(3)When it is important that agents have behaviors that reflect how individuals actually behave (if known), (4) When it is important that agents adapt and change their behaviors, (5) When it is important that agents learn and engage in dynamic strategic interactions (6)When the past is no predictor of the future because the processes of growth and change are dynamic, (7) When process structural change needs to be an endogenous result of the model, rather than an input to the model.

3.4.2 ABMS Methodology overview

As advised by Garro & Russo (2010), this study used the ABMS (Agent Based Modeling and Simulation) methodology to address the research problem. Agent Based Modeling and Simulation (ABMS) represents a new and powerful way for analyzing and modeling complex systems as it is able to fully represent a system at different levels of complexity in terms of autonomous, goal-driven and interacting entities (agents) organized into societies which exhibit emergent properties, that is, properties which arise from the interactions between the component entities and that cannot be deduced a priori simply considering only the properties of the individual entities (Garro & Russo 2010).

We have explained the following phases as supported by our methodology: System analysis ,Conceptual system modeling, Simulation Design, Simulation Code Generation, Simulation Set-up, Simulation Execution and Simulation Results Analysis . In each of these phases, we have indicated the appropriate work product.

3.4.2.1 System Analysis

In this phase we will construct an analysis statement, which shall be our work product. We will highlight the composition of entities and their intra-relationship. Ends when the user obtains a System Representation in which each component (pro-active, re-active, passive) entity has been represented at the level of abstraction which is appropriate for the objectives of the simulation.

3.4.2.2 Conceptual System modeling

We will build the conceptual system model which will comprise of the Artifact Model, Agent Model, Society Model and Structural System Model. The Structural System Model for each entity in the System Representation is produced.

- Artifact Model: describes the behavior of an Artifact as a set of triggered Activities
- Agent Model: describes the complex goal of an Agent.

- Society Model: describes the entities which compose a Society, their type (Agent, Artifact, Society), and the rules governing the Society (safety rules) and its evolution (liveness rules).
- Structural System Model: is a model describing Agent model, Artifact model, Society model.

3.4.2.3 Simulation Design

Starts from the Conceptual System Model, we produce a Simulation Model of the system, in terms of the abstractions offered by the framework exploited for the simulation is produced.

3.4.2.4 Simulation code Generation

We use the model in the previous phase to automatically generate the Simulation Code for the target simulation environment.

3.4.2.5 Simulation set up

We establish Simulation Scenarios.

3.4.2.6 Simulation excecution and Simulation Result Analysis

We analyze the simulation results with reference to the objectives of the simulation previously identified in the System Analysis phase.

3.4.3 ABMS process

easyABMS defines a process which is: (i) complete as its phases cover from the analysis of the system under consideration to its modeling and simulation analysis; (ii) integrated as each phase refines the model of the system which has been produced in the preceding phase; (iii) visual as the work-products of each phase are basically different models of the system mainly constituted by visual diagrams based on the UML notation (Object Management Group Inc. 2007); (iv) model driven as according to the Model Driven paradigm (Atkinson and Kühne 2003 &Schmidt 2006) the simulation code is automatically generated from the obtained

Simulation Model of the system; (v) iterative as, on the basis of the simulation results, a new/modified and/or refined model of the system can be obtained through a new process iteration which can involve all or some process phases.

Process phase	System analysis	Conceptual system modeling	Simulation Design	Simulation Code Generation	Simulation Set-up	Simulation Execution	Simulation Results Analysis
Work Product	Analysis Statement	Conceptual System Model : • Structural System Model • Society Model • Agent Model : o Goal Model o Behavioral Model o Interaction Model • Artifact Model : o Behavioral Model o Interaction Model	Simulation Model : • Simulation Context Model • Simulation Agent Model	Simulation Code	Simulation Scenarios	Simulation Results	Simulation Analysis Reports
Main concept	Composed entity	Society	Simulation Context	Java classes	Depending on the features of the exploited Simulation Framework		
	Pro-active entity	Agent	Simulation Agent				
	Re-active entity	Artifact					
	Passive entity	Artifact (Resource Manager of the passive entity)					
	Intra-entity relationship	Interaction	Depending on the features of the exploited Simulation Framework				
	Inter-entity relationship						

Table 3-1. *EasyABMS process phases, work products and main related concepts.*

Using our methodology, we defined a process for ABMS as having composed of seven subsequent phases from the preliminary System Analysis to the Simulation Result Analysis. On the basis of the obtained simulation results a new iteration of the process which can involve all or some process phases can be executed for achieving new or not yet reached simulation objectives (Garro & Russo 2010).

3.5 Data collection methods and tools

In our project we will collect data through experiments and observation method, and get data from Kenya Fire Brigade (Nairobi). According to Ferworn (2007), data collection using observation and experimental methods are done mainly to give us original data from the experiments conducted on agent to verify if it functions as required. The fundamental reason as to why we incorporating this method of data collection is that, it is cheaper, faster and less involving as suggested by Chauhan (1997).

3.6 System implementation and testing

We need to set up the following; - install JVM or JRE for running java, install eclipse, AnyLogic and or Repast Simphony IDE then we are ready to build the computer implementation of the conceptual model and perform several runs. Testing is supported in our methodology.

3.7 Data analysis and Evaluation

In analysis we intend to capture the screenshot of the results, graphs and tables. We will analyze data with regard to real life experience and set some controls. In analysis and evaluation we intend to compare the data that agents will produce under various conditions and the actual information provided by the fire department. Part of this is covered in our methodology

3.8 Limitation of the methodology

As argued by Salamon (2011), there is a lack of practical applications and a very low awareness of this methodology in the scientific community.

4. CHAPTER FOUR: Model Analysis, Design and Implementation

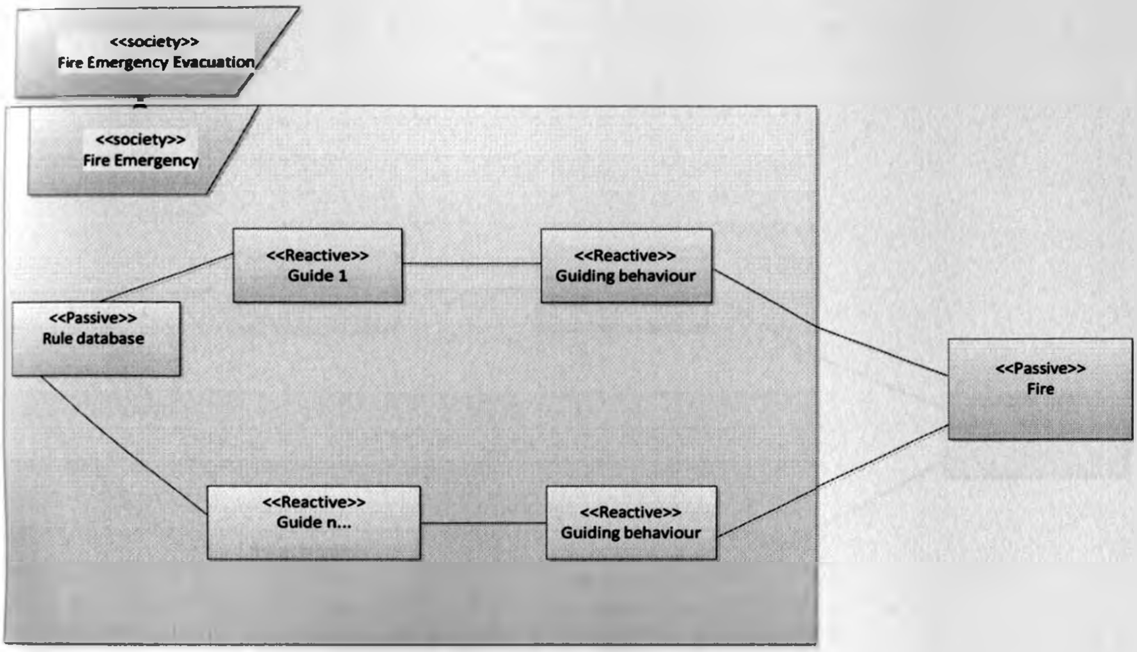
4.1 model analysis

According to (Garro & Russo 2010), model/system analysis based on ABMS is done by obtaining a System representation, which highlights the component and their relationships. The work product here is producing the analysis statement; which consists of the description of entities (proactive, reactive entities & passive), and identifying their relationships (intra-relationship and inter-relationship).

We identified and established the participating entities characteristics by specifying their behaviour; autonomous and goal oriented behavior (pro-active entity), by a pure stimulus-response behavior (re-active entity), or can be passive; It is followed by establishing the rules governing entities and their evolution, and finally the relationships among entities.

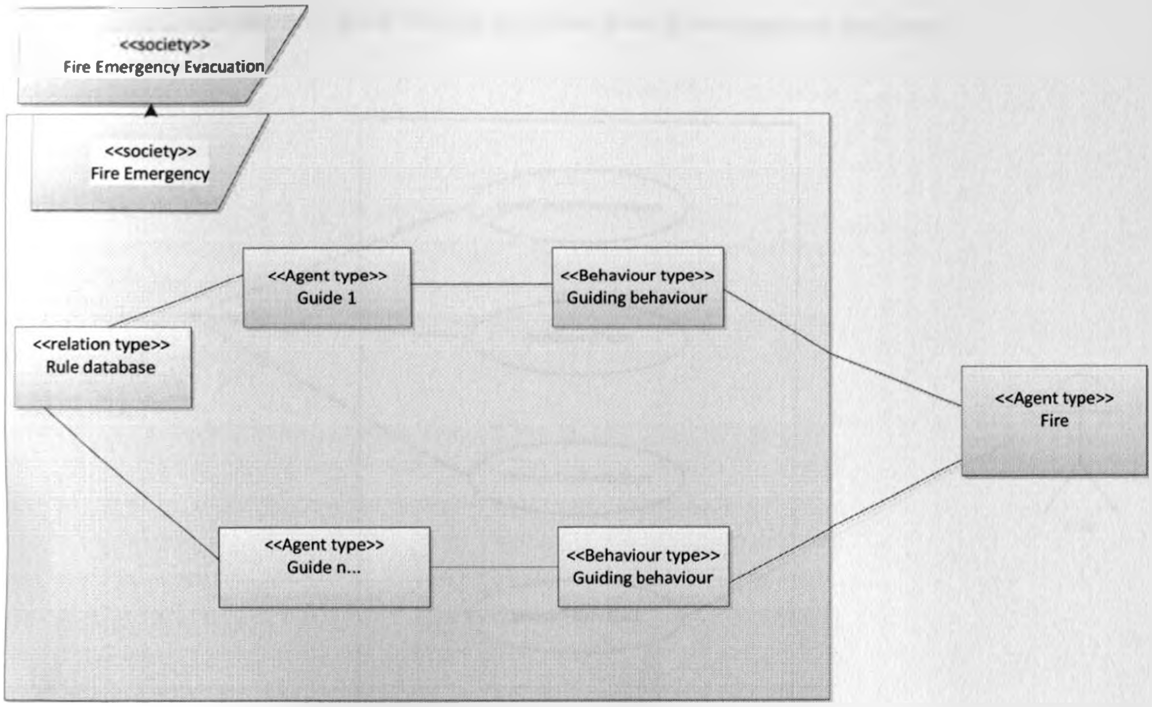
Afterwards we specified the Safety and liveness rules; note that safety rules determine the acceptable and representative states of an entity whereas liveness rules determine which state transitions are feasible during the entity evolution.

We obtained a Representation of the system in which each component entity has been represented at the level of abstraction which is appropriate for the objectives of the simulation. Figure 3 shows the system representation obtained from system analysis phase, while Figure 4 shows the structural system model.



Conceptual Model Class Diagram for EvacSim world

Figure 4-1. *Overview of system representation obtained from system analysis phase*



Conceptual Model Class Diagram for EvacSim world

Figure 4-2. *Overview of the structural system model obtained in the conceptual modeling phase*

4.2 Model design (Simulation model)

An intelligent agent operates in an environment which it perceives changes and takes action that might transform the environment from one state to the other. The environment in which agents in this model operates is dynamic and fully observable. This is because the final decision made depends on the independent analysis carried out by the agents. The information agents are using is making decisions is fully made available to them making that environment fully observable.

We express our simulation model by providing the simulation context model shown in Figure 5; the conceptual model shown in Figure 6; the simulation process shown in Figure 7 and the agent model shown in Figure 8.

Use Case Diagram for the Simulation Model

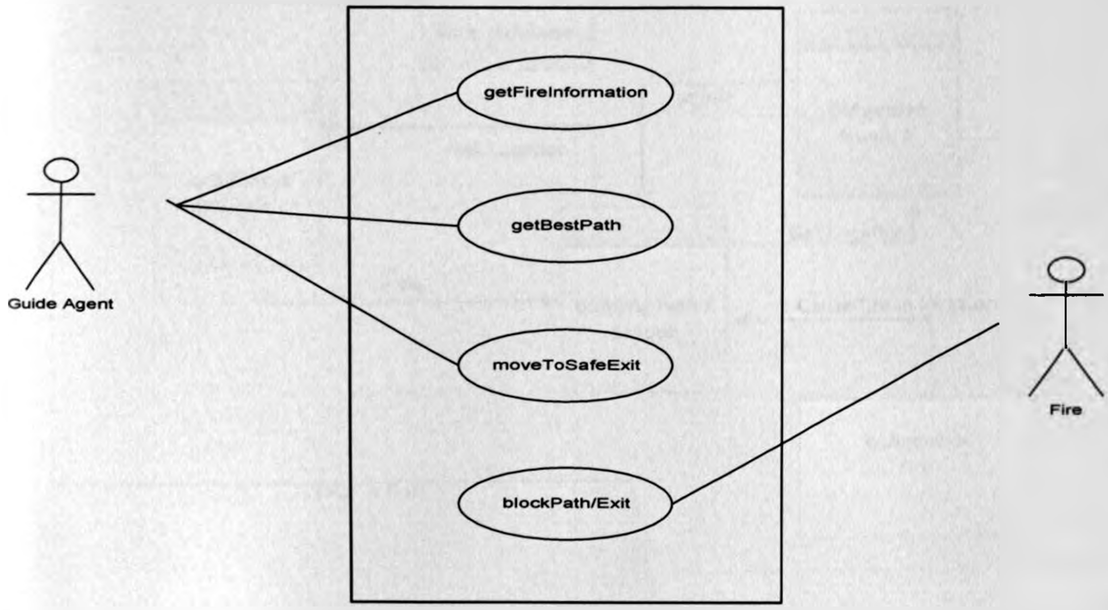
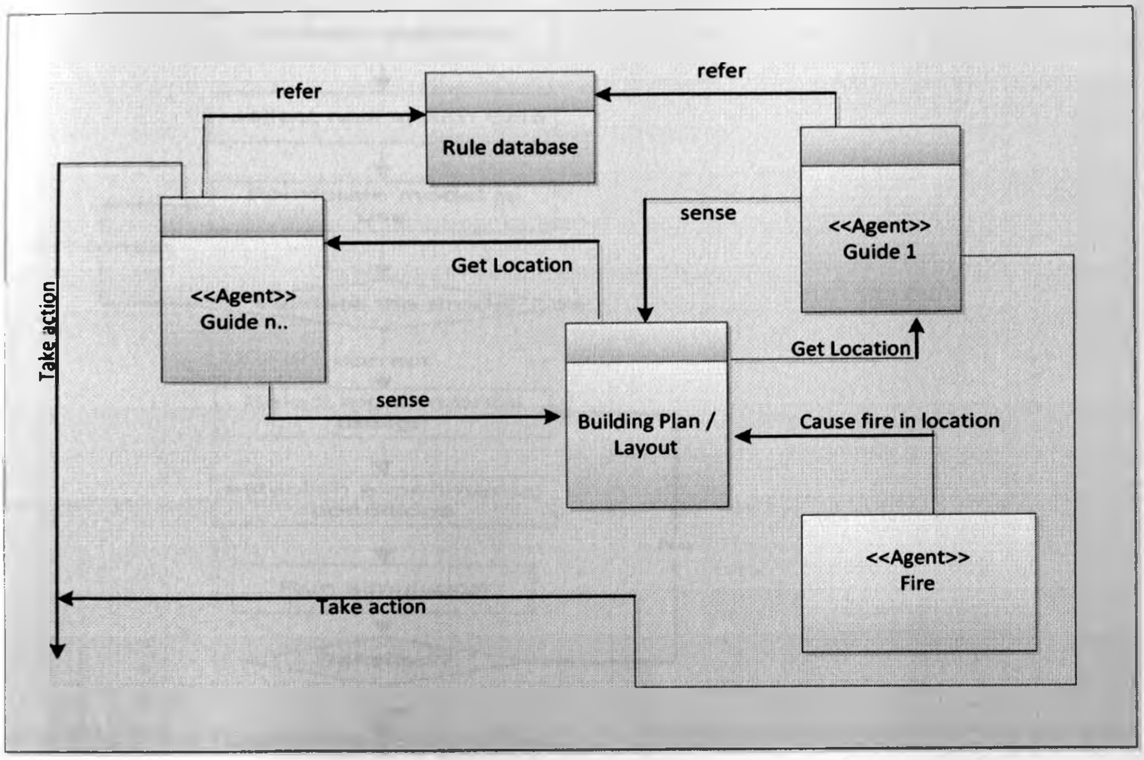


Figure 4-3. *Use case diagram for the simulation context*



EvacSim Conceptual Model

Figure 4-4. *Conceptual model for EvacSim world.*

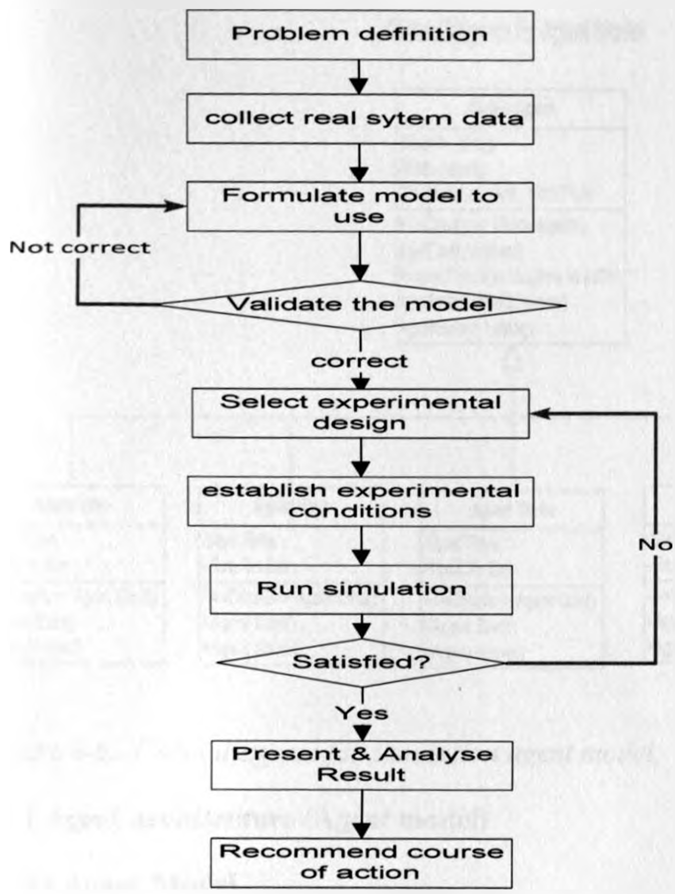


Figure 4-5. *The simulation process.*

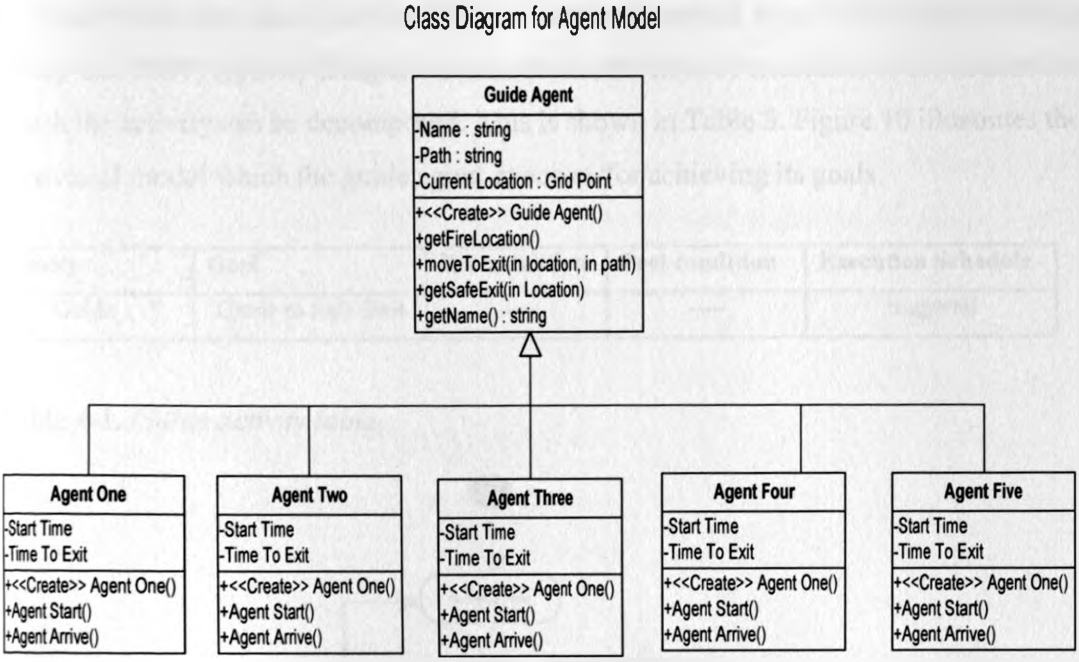


Figure 4-6. *Class diagram for simulation agent model.*

4.2.1 Agent architecture (Agent model)

Guide Agent Model

A complete Guide Agent Model containts the goal model, behavoiur model and actyivity model . Part of the Agent Model of the guide Agent is shown to be precise we show the Guide Agent Goal Model as illustrated in figure 9. The goal of guiding occupant to safe exit is achieved independently.

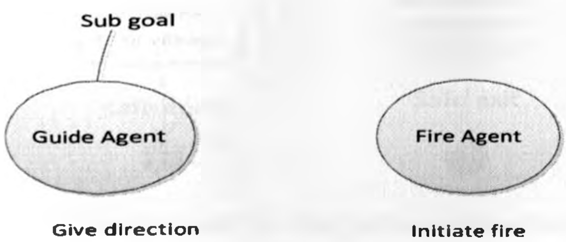


Figure 4-7. *The guide agent goal model*

Each activity in the Agent Activity Table is further described by: a UML (Object Management Group Inc. 2007) Activity Diagram which details the flow of execution of the actions into which the activity can be decomposed. This is shown in Table 3. Figure 10 illustrates the behavioral model which the guide agent executes for achieving its goals.

Activity	Goal	Pre condition	Post condition	Execution Schedule
Guide	Guide to Safe Exit	----	----	triggered

Table 4-1. *Guide activity table.*

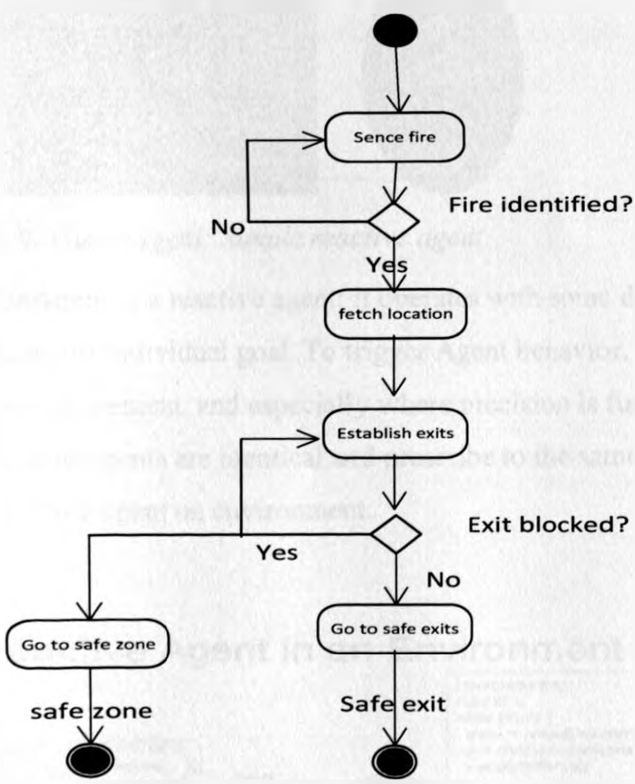


Figure 4-8 *UML activity diagram for evacuation activity, in the EvacSim world.*

Guide behavioral model

initiator	Activity	Partner
fire	Guide to Safe Exit	guide

Table 4-2. *Guide interaction model*

4.2.2 Agent design

The architectural design adopted for each of the agents is that of simple reactive agents. In this architecture the conditions - action rules allow agents to make a connection from percept to action the percept in this model are made up of the data about state of fire emergency in the room where each agent reacts immediately to pursue its goal of getting out safely. The architecture is presented in the schematic diagram below.

A Simple Reactive Agent

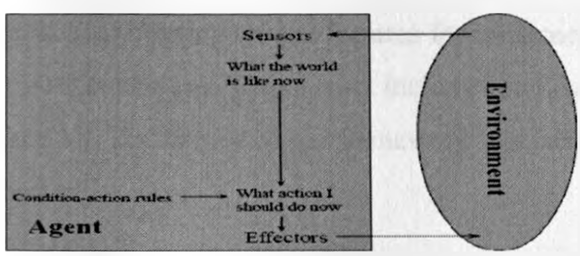


Figure 4-9. *GuideAgent: Simple reactive agent*

The GuideAgent is a reactive agent; it operates with some degree of autonomy and concentrates on individual goal. To trigger Agent behavior, Events have been used; events seem more convenient, and especially where precision is fundamental. It's important to note that the GuideAgents are identical and prescribe to the same architecture. Figure 12 illustrates a simple reactive agent on environment.

A Reactive Agent in an Environment

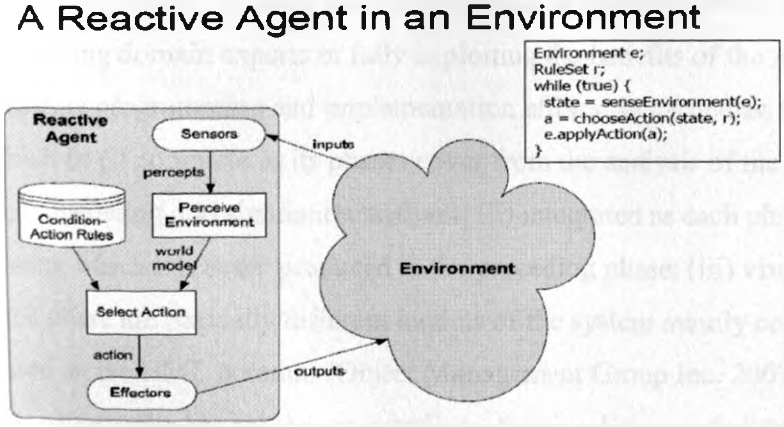


Figure 4-10. *GuideAgent: Simple reactive agent on environment*

4.2.3 GuideAgent Actions

The guideAgents may trigger different reactive behaviour, this include;-

- Move to exit 1
- Move to exit 2
- Move to safety location

4.3 Agent development platform and framework

A variety of frameworks and platforms exist for agent development with each of the framework exhibiting unique features for implementing agents. The various frameworks that have been considered in this work include AnyLogic, Jason, mason, jade, Repast symphony and madkit. The choice of our framework was based on merits and demerits of the considered framework.

4.4 Implementation framework

This model has been implemented within the ABMS (AnyLogic) development framework.

4.4.1 Why ABMS

Agent Based Modeling and Simulation (ABMS) represents a new and powerful way for analyzing and modeling complex systems as it is able to fully represent a system at different levels of complexity in terms of autonomous, goal-driven and interacting entities (agents) organized into societies which exhibit emergent properties (Garro & Russo 2010). Besides there's availability of tools for ABMS (Minar & Burkhart 1996). EasyABMS aims at supporting domain experts in fully exploiting the benefits of the ABMS while significantly reducing programming and implementation efforts; in particular, easyABMS defines a process which is: (i) complete as its phases cover from the analysis of the system under consideration to its modeling and simulation analysis; (ii) integrated as each phase refines the model of the system which has been produced in the preceding phase; (iii) visual as the work-products of each phase are basically different models of the system mainly constituted by visual diagrams based on the UML notation (Object Management Group Inc. 2007); (iv) model-driven as according to the Model Driven paradigm, the simulation code is automatically generated from the obtained Simulation Model of the system; (v) iterative as, on the basis of the simulation results, a new/modified and/or refined model of the system can be obtained through a new process iteration which can involve all or some process phases.

4.4.2 Why AnyLogic

AnyLogic ranks superior in that it offers a number of advantages in simulation. These include the following: - (i) A Multi-paradigm approach to simulation; arguably, it's one of the few software that supports Multi-paradigm approach to simulation. (ii) Models can contain approaches taken from Discrete Event and System Dynamics. (iii) Integrating Agent-based concepts is simple. (iv) Its ability to Handles complex systems. (v) Change the focus from being on the modeling approach, to start focusing on the problem.

4.4.3 Implementation of agents

Agents are implemented as active objects. Active object is an instance of an active object class. Active objects classes are developed by the user, or they can be taken from libraries. These Active objects are main building blocks of AnyLogic model. Active objects can be used to model very diverse objects of the real world: in our case it has been used to model occupants / people.

By declaring an agent, you tell AnyLogic that your active object class is a subclass of AnyLogic built-in class Agent, which extends the class ActiveObject. This class allows different agents to share the same environment. The environment is specified at the instances of the active object class (i.e. where it is embedded).

5. CHAPTER FIVE: Experimentation, results & discussion (simulation setup and execution)

5.1 Simulation setup

During the simulation setup, tests were done after the completion of each generation to check and debug them if needed. Tests were done against different agents to detect different behaviour and check the rationality of the agent's behaviour.

When the model is executed it starts with a GUI which highlights a building layout both on 2 and 3 dimensions. Five agents strategically positioned in different rooms within the building immediately respond to a fire emergency by getting out to safety and their evacuation time recorded.

In the event of no fire emergency, the guide agents are calm and incase they are required to leave the room under normal circumstances they will do so depending on their selfish interest.

In the event of fire, agents are triggered to act; their actions are stratified into two: (1) when agents seem to know about the fire, and the affected exit point; and (2) when agents seem to be aware of the fire but do not know the affected exit point(s).

We further classified this under three scenarios which included:-

Evacuation Scenario 1 - when only exit one is blocked

Evacuation when fire has blocked completely exit one by the time the first occupant gets there.

Evacuation Scenario 2 - when only exit two is blocked

Evacuation when fire has blocked completely exit two by the time the first occupant gets there.

Evacuation Scenario 3 - when both exits are blocked

Evacuation when fire has blocked completely both exit one and exit two by the time the first occupant gets there.

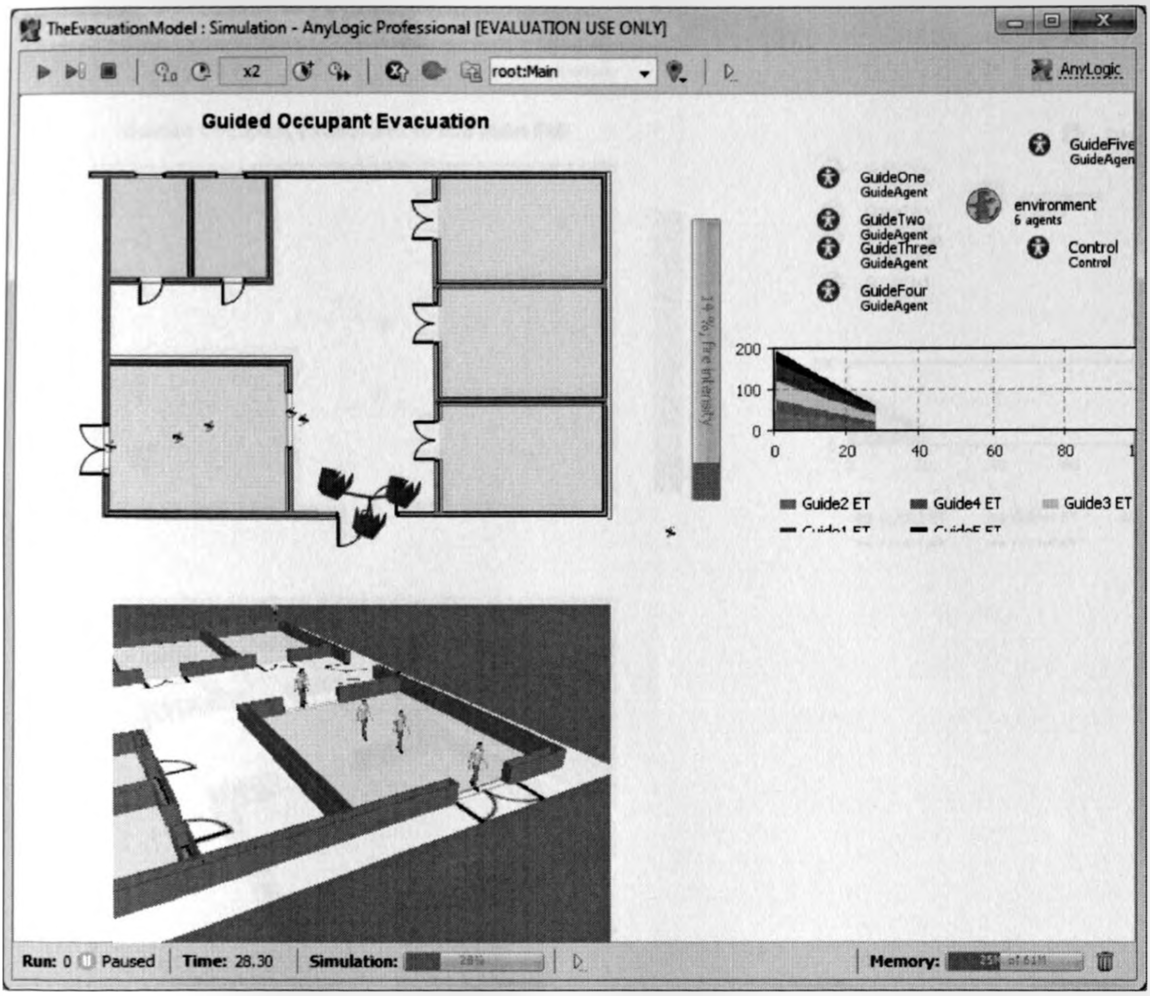


Figure 5-1. *Guided evacuation when main exit is blocked.*

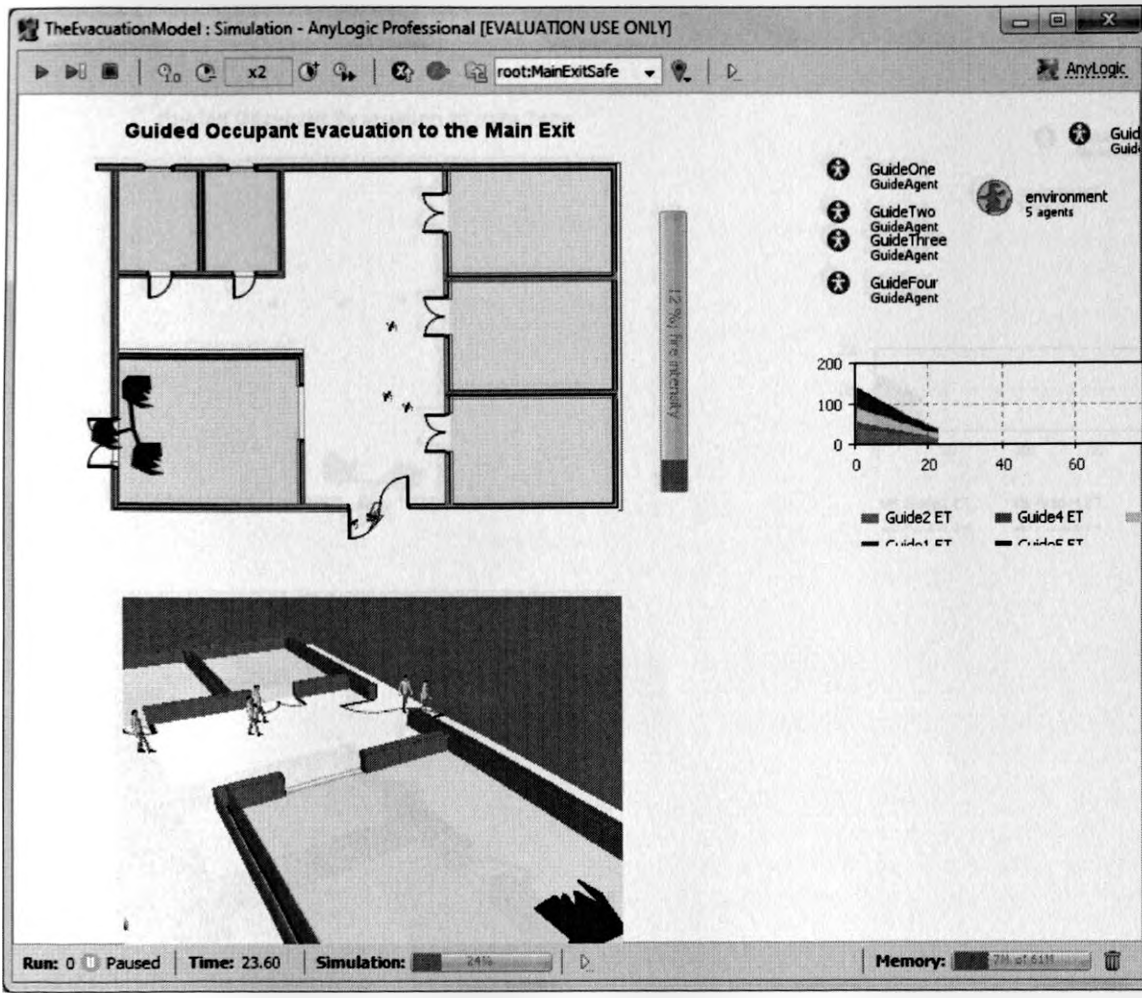


Figure 5-2. *Guided evacuation when main exit is safe.*

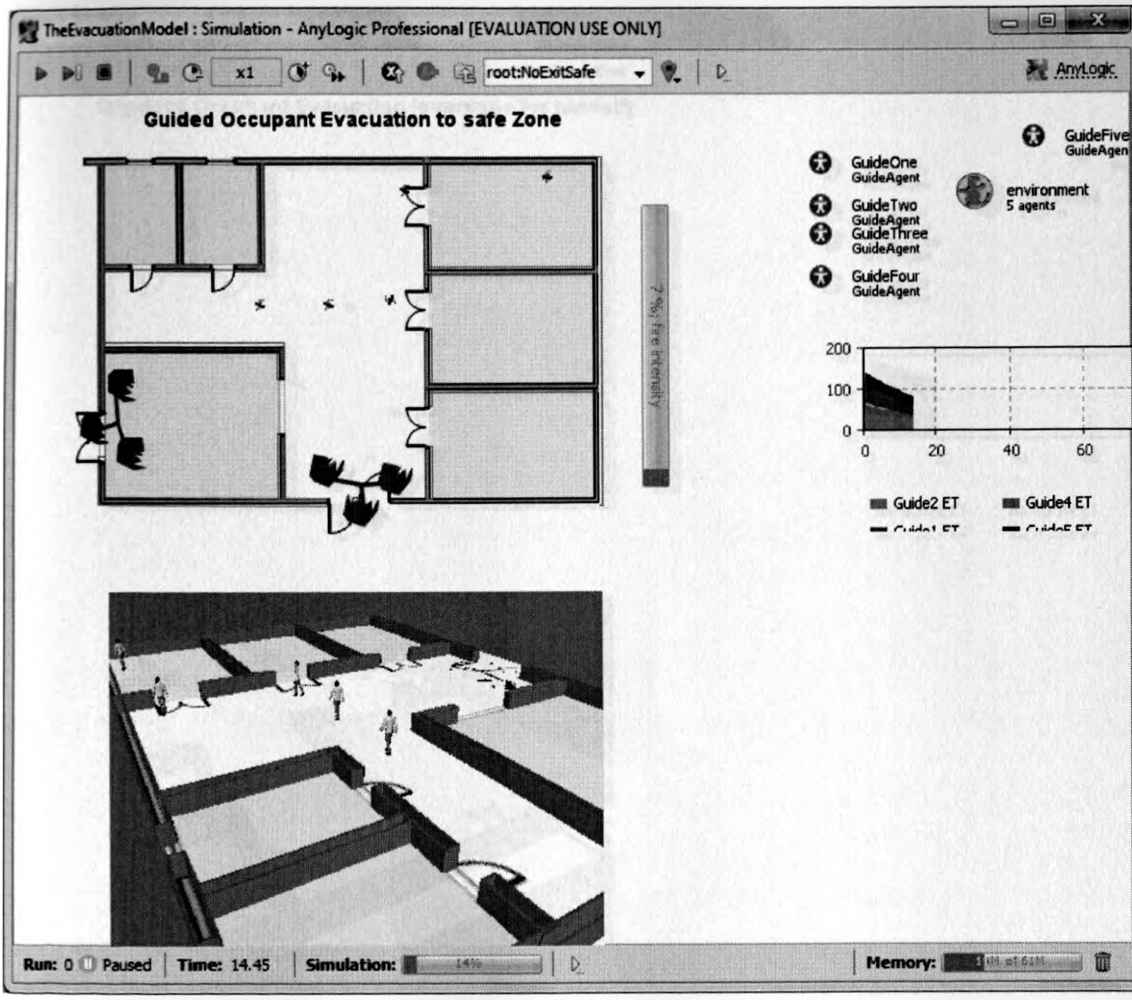


Figure 5-3. *Guided evacuation when both exits are blocked.*

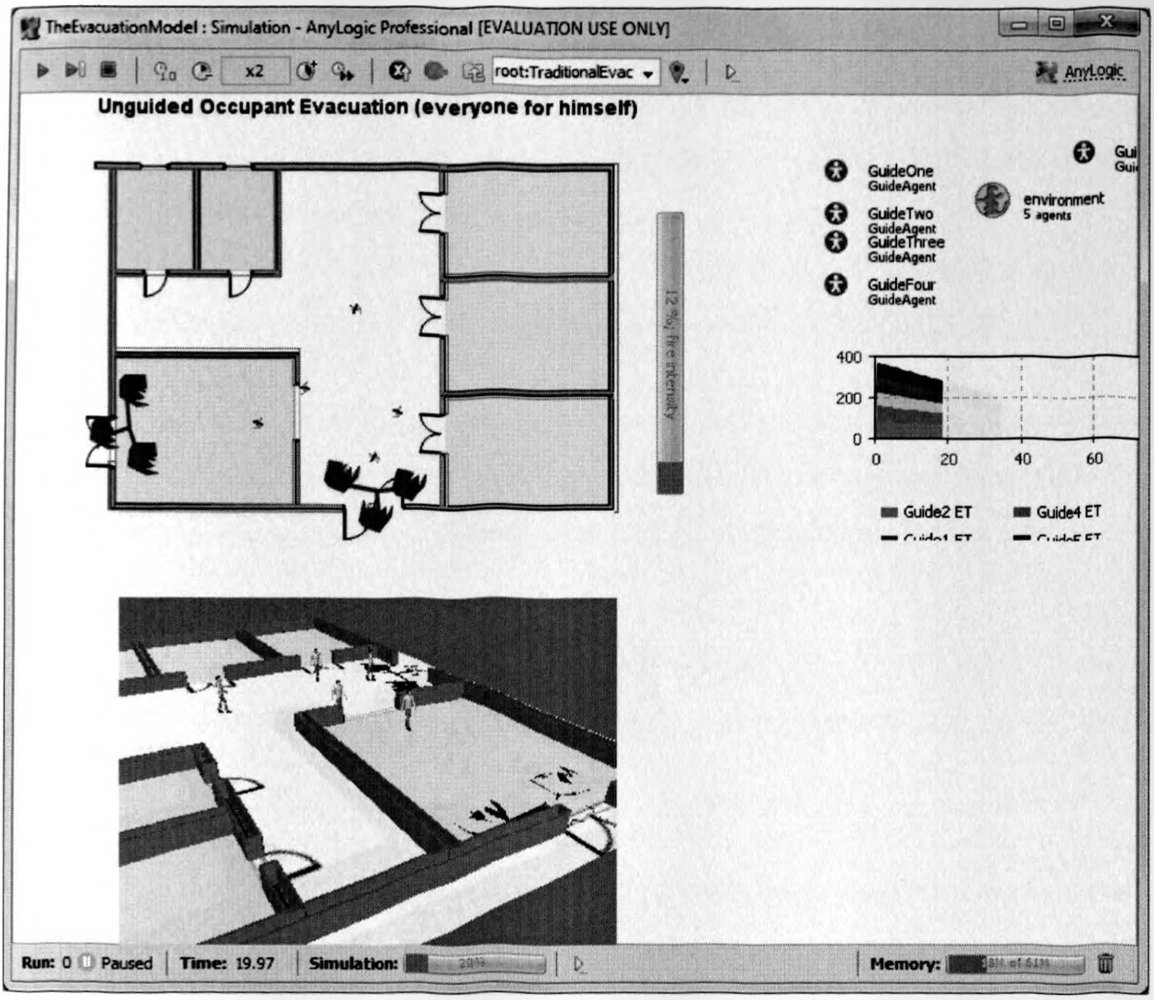


Figure 5-4. *Unguided / traditional evacuation when both exits are blocked.*

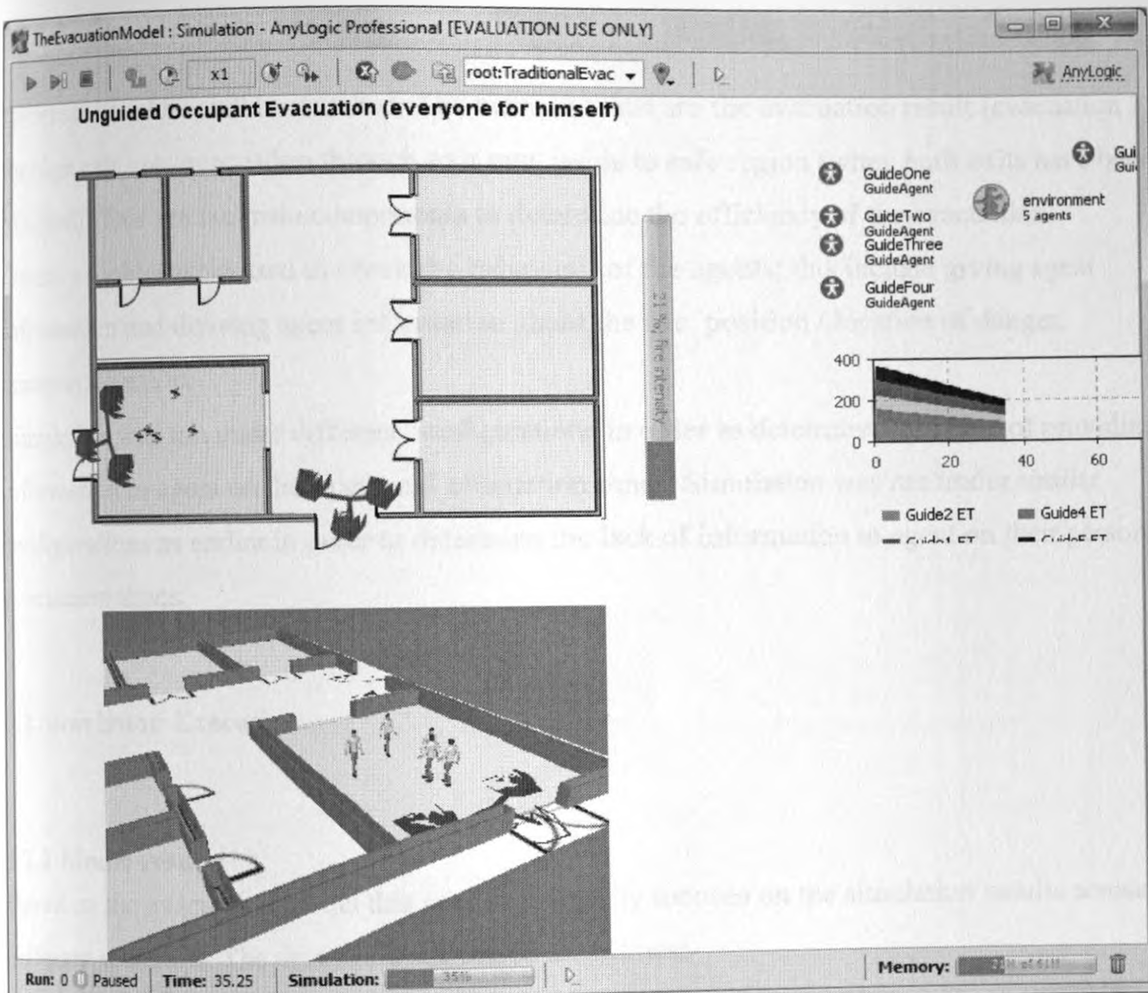


Figure 5-5. *Unguided / traditional evacuation when both exits are blocked.*

5.1.1 Debugging and adjustments

As direct observation of the agent was not sufficient to ensure the working of different mechanisms, debugging had to be more precise.

When a problem, was suspected, tracing messages were used to watch the value of some variable at specific points. Triggering the chatty variable of rules family also enabled a more precise control of what was done.

When the mechanism worked, it was still needed to adjust empirical value to get a greater efficiency.

5.1.2 Project parameters as input

Different variables will be watched. The more obvious are the evacuation result (evacuation through exit one, evacuation through exit two, guide to safe region (when both exits have been blocked)).This are the main components to determine the efficiency of the evacuation.
Others variables were used to check the behaviour of the agents; this include giving agent information and denying agent information about the fire, position / location of danger, occupant location.
Simulation was run under different configurations in order to determine the effect of providing information to agent on their personal evacuation times. Simulation was run under similar configurations as earlier in order to determine the lack of information to agent on their personal evacuation times.

5.2 Simulation Execution

5.2.1 Model results

Based on the evacuation model this section primarily focuses on the simulation results across different scenarios. The details are addressed as follows;-

Evacuation Scenario 1

Based on Table 5, the personal evacuation times for each agent has been recorded, for the situation where fire has blocked completely exit one. The least time for all five agents to get to safety is 44.99 time units when they are guided whereas the least time for all five agents to get to safety is 59.20 time units when they are not guided.

guided			not guided	
when exit one is blocked				
	PET		PET	CWT
Occupant One	44.99		59.20	14.21
Occupant Two	38.99		54.30	15.31
Occupant Three	44.95		51.43	6.48
Occupant four	35.87		46.55	10.68
Occupant five	31.19		35.43	4.24
All Together	44.99		59.20	14.21

Table 5-1. *Evacuation results when exit one is blocked.*

Figure 18. depicts a comparison on personal evacuation times for occupants placed in the same location in the building.

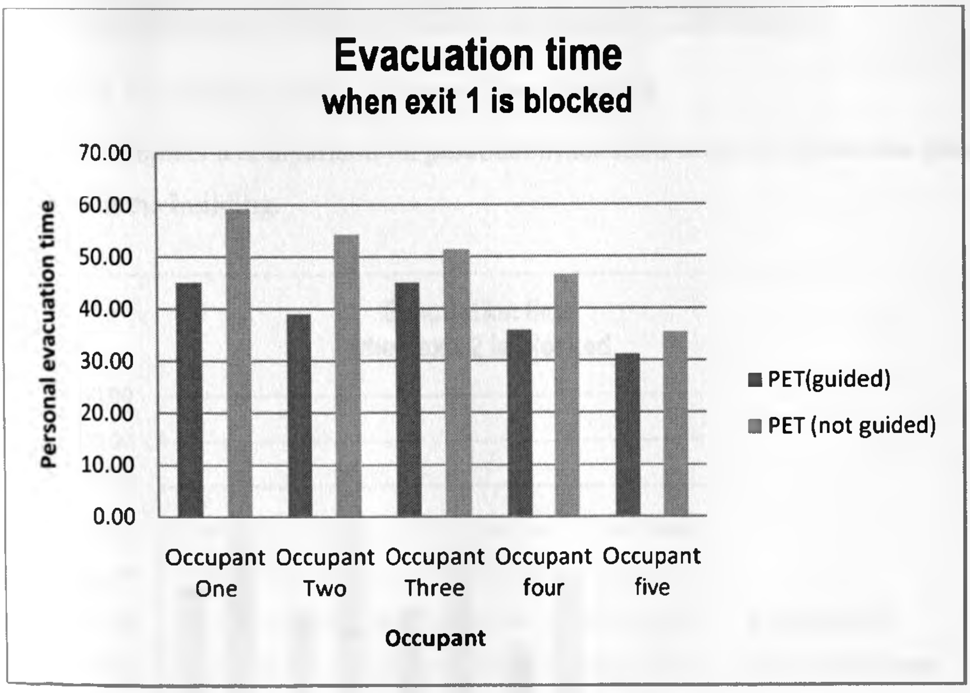


Figure 5-6. *Comparison of evacuation times when exit 1 is blocked, results from table 5-1.*

Evacuation Scenario 2 - when only exit two is blocked

Based on Table 6, the personal evacuation time for each agent has been recorded, for the situation where fire has blocked completely exit two. The least time for all five agents to get to safety is 37.82 time units when they are guided whereas the least time for all five agents to get to safety is 69.95 time units when they are not guided.

guided **not guided**

when exit two is blocked				
	PET		PET	CWT
Occupant One	37.82		69.95	32.13
Occupant Two	32.92		65.43	32.51
Occupant Three	33.08		45.73	12.65
Occupant four	24.38		40.44	16.06
Occupant five	12.15		12.15	0.00
All Together	37.82		69.95	32.13

Table 5-2. *Evacuation results when exit two is blocked.*

Figure 19. depicts a comparison on personal evacuation times for occupants placed in the same location in the building.

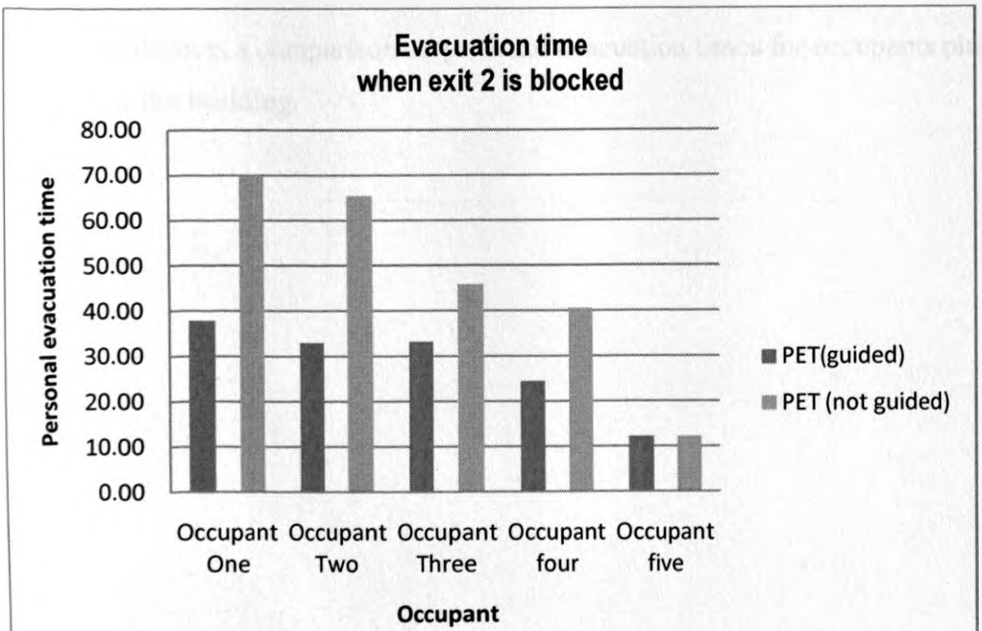


Figure 5-7. *Comparison of evacuation times when exit 2 is blocked, results from table 5-2.*

Evacuation Scenario 3

Based on Table 7, the personal evacuation time for each agent has been recorded, for the situation where fire has blocked completely exit one and two. The least time for all five agents to get to safety is 40.51 time units when they are guided whereas the least time for all five agents to get to safety is 80.63 time units when they are not guided.

guided			not guided	
when both exits are blocked				
	PET		**PET**	**CWT**
Occupant One	40.51		73.70	33.19
Occupant Two	35.61		80.63	45.02
Occupant Three	6.66		65.73	59.07
Occupant four	24.66		75.26	50.60
Occupant five	32.74		72.88	40.14
All Together	40.51		80.63	40.12

Table 5-3. *Evacuation results when both exits (one and two) are blocked.*

Figure 20. depicts a comparison on personal evacuation times for occupants placed in the same location in the building.

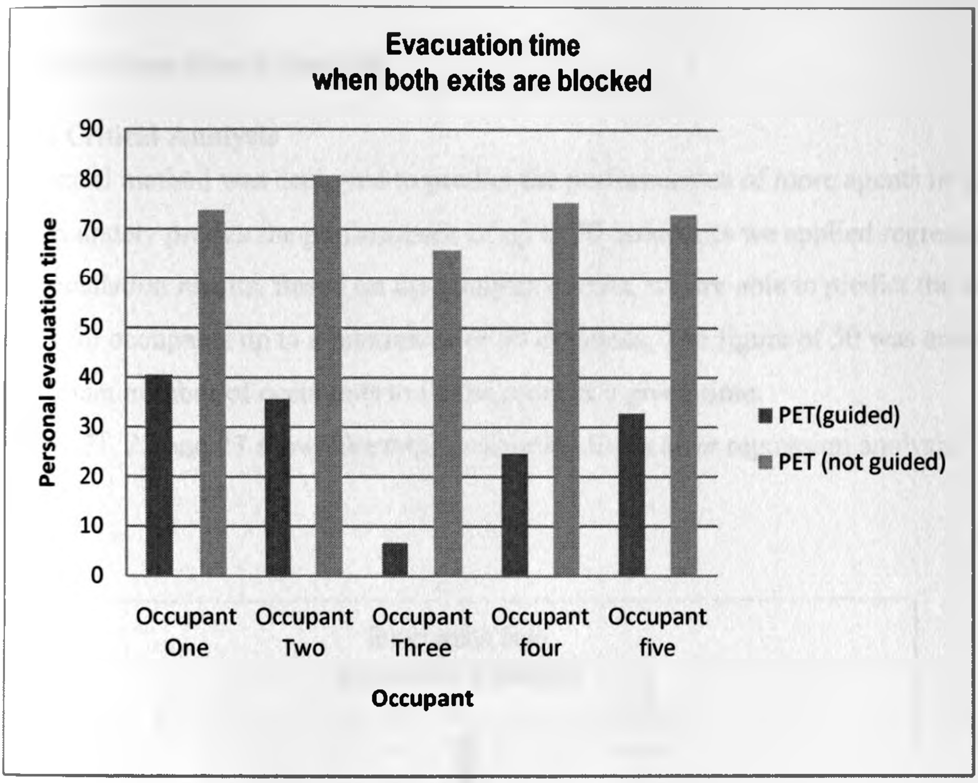


Figure 5-8. *Comparison of evacuation times when both exits are blocked, results from table 5-3.*

5.3 Simulation Result Analysis

5.3.1 Critical Analysis

Statistical method was deployed to predict the performances of more agents in the world.

To accurately predict the performance of up to 50 occupants we applied regression analysis on our simulation results. Based on the analysis of data, we are able to predict the total evacuation times for occupants up to a maximum of 50 evacuees. The figure of 50 was arrived at as the maximum number of occupants to fit the room at a given time.

Figure 21, 22 and 23 shows the total evacuation times after regression analysis.

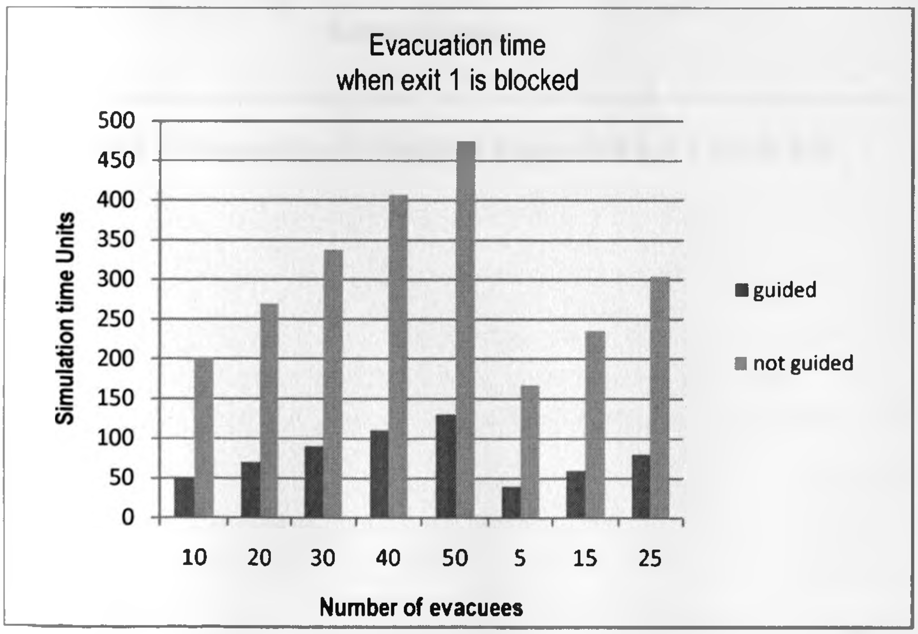


Figure 5-9. *Comparison of evacuation times when exit 1 is blocked.*

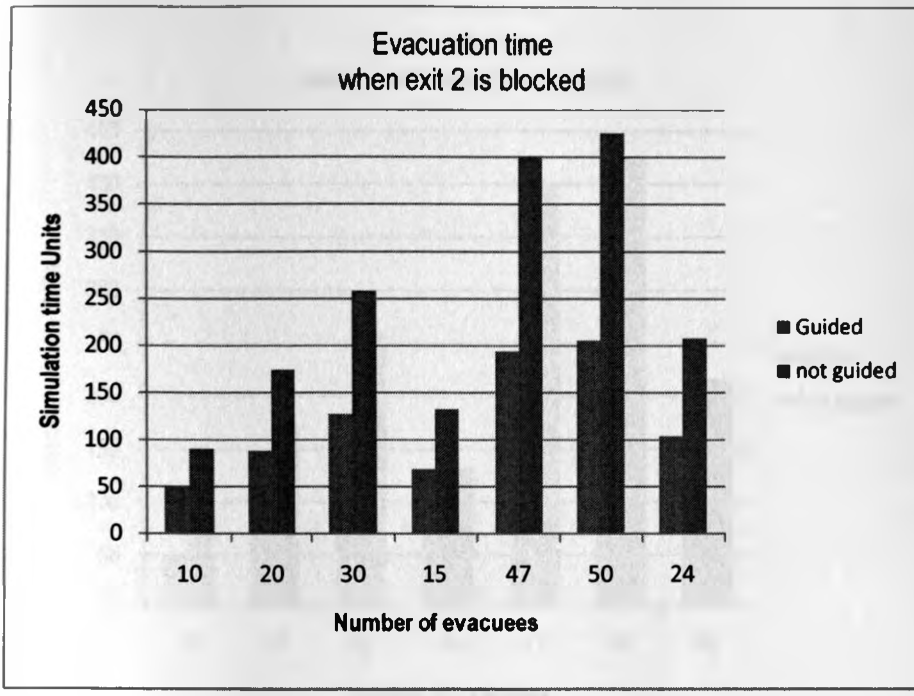


Figure 5-10. *Comparison of evacuation times when exit 2 is blocked.*

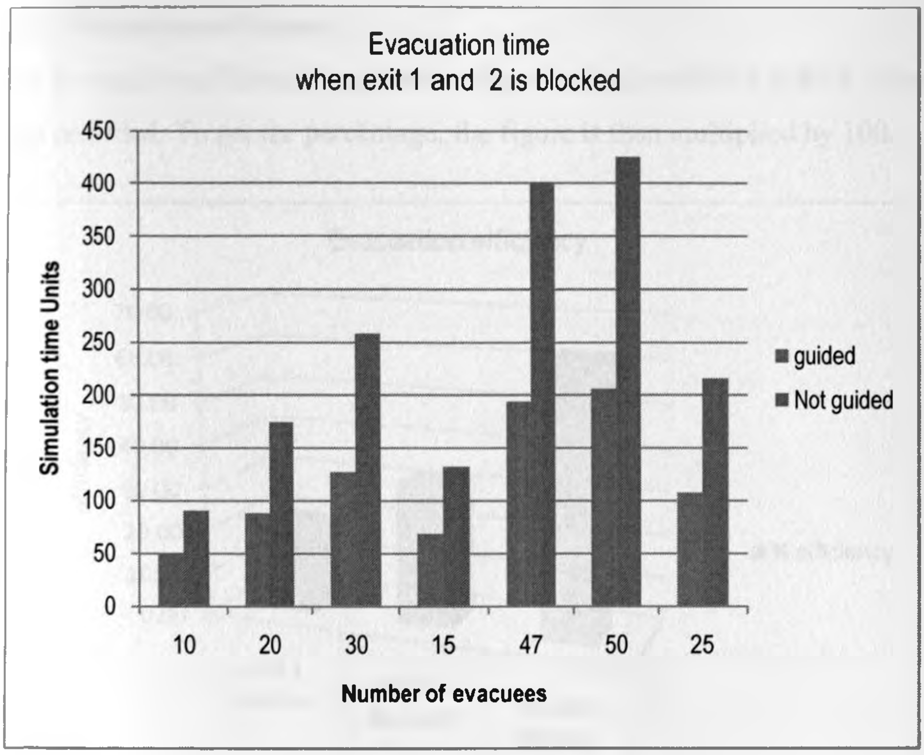


Figure 5-11. *Comparison of evacuation times when both exits are blocked.*

From figures 21, 22 and 23; we note that the evacuation times in cases where no guide was provided appears high even after varying the number of occupants. If the trend is continued without abating, it would suggest that guiding occupants reduces their evacuation times greatly.

5.3.2 Evacuation efficiency

The Evacuation efficiency was derived from the ratio of CWT to PEV when no information was provided. To get the percentage, the figure is then multiplied by 100.

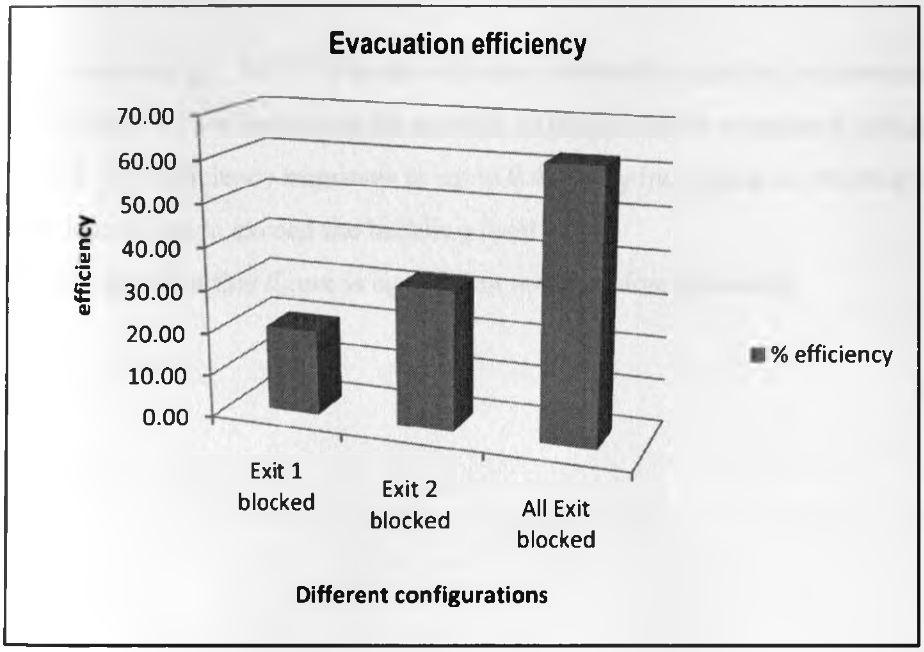


Figure 5-12 *Evacuation efficiency in percentage.*

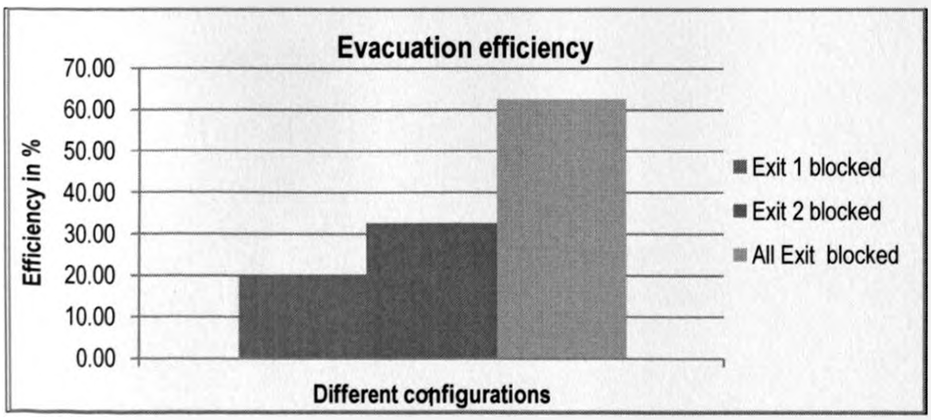


Figure 5-13. *Evacuation efficiency in percentage.*

To determine the general efficiency in evacuation we can apply the formula.

$$1/n \sum_{i=1}^{n} si$$

Where: n is the number of evacuees; S is the evacuation scenario.

In our case we get, 38.38 % as the efficiency derived by guiding occupants at any given time. This means we are increasing the number of people safely evacuated during a fire event by 0.3838. The efficiency improves to up to 0.44 % by increasing the number of occupants. It is only logical not to exceed the building limit.

It is obvious that this figure is significant and therefore necessary.

6. CHAPTER SIX: conclusion and recommendation

Based on the results from our simulation experiment it has been shown that guiding evacuees improves greatly the evacuation times (provides a good overall performance), thereby allowing more occupants be evacuated within shorter times. This will help realize a larger number of evacuees safely evacuated.

A large value for evacuation times suggests that the evacuation was highly inefficient, with most of the evacuation time lost in indecision and confusion.

Our experiment predicts an evacuation efficiency of 38.38 %, derived from guiding occupants during fire emergency. The value of efficiency increases as the number of occupants increases; this will only apply as long as we don't exceed the building limit.

6.1 Recommendations

In future work we, recommend the creating of the evacuation guide prototype to be installed in buildings as it will greatly improve evacuation in case of fire emergency.

6.2 Future Study

The simulation model developed in this project is only the beginning of the research in this area, and there are several interesting areas that need study further. These include
(1) Creating a system, (2) Evacuee modeling etc.

7. CHAPTER SEVEN: Project plan and Management

We present the overall plan of activities in our undertaking; specify the duration and the budget.

7.1 Time plan

NB. The date format in the Gantt chart takes the format: yyy / month / day

ID	ℹ	Task Name	Duration	Start	Finish	Predecessors
1		System Analysis	14 days	Thu 12/01/26	Tue 12/02/14	
2		Conceptual System Modeling	19 days	Wed 12/02/15	Mon 12/03/12	1
3		Simulation Design	19 days	Tue 12/03/13	Fri 12/04/06	2
4		Simulation Code Generation	18 days	Mon 12/04/09	Wed 12/05/02	3
5		Simulation Set - Up	14 days	Thu 12/05/03	Tue 12/05/22	4
6		Simulation Excecution	5 days	Wed 12/05/23	Tue 12/05/29	5
7		Simulation Results Analysis	7 days	Wed 12/05/30	Thu 12/06/07	6

Table 7-1. *Time plan*

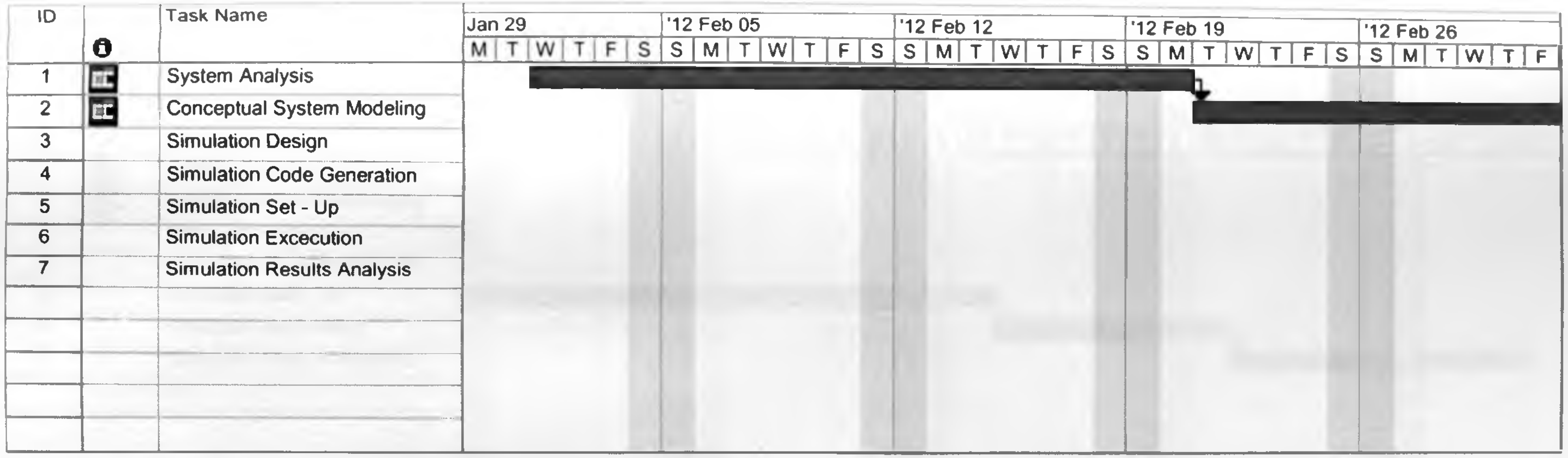


Figure 7-1. *Gantt Chart part 1*

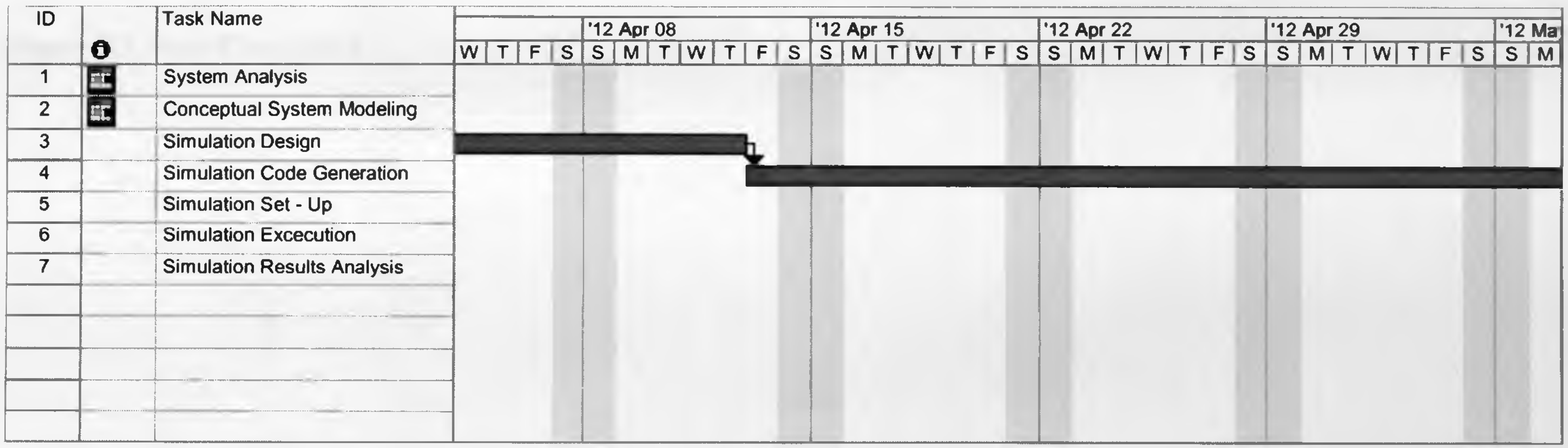


Figure 7-2. *Gantt Chart part 2*

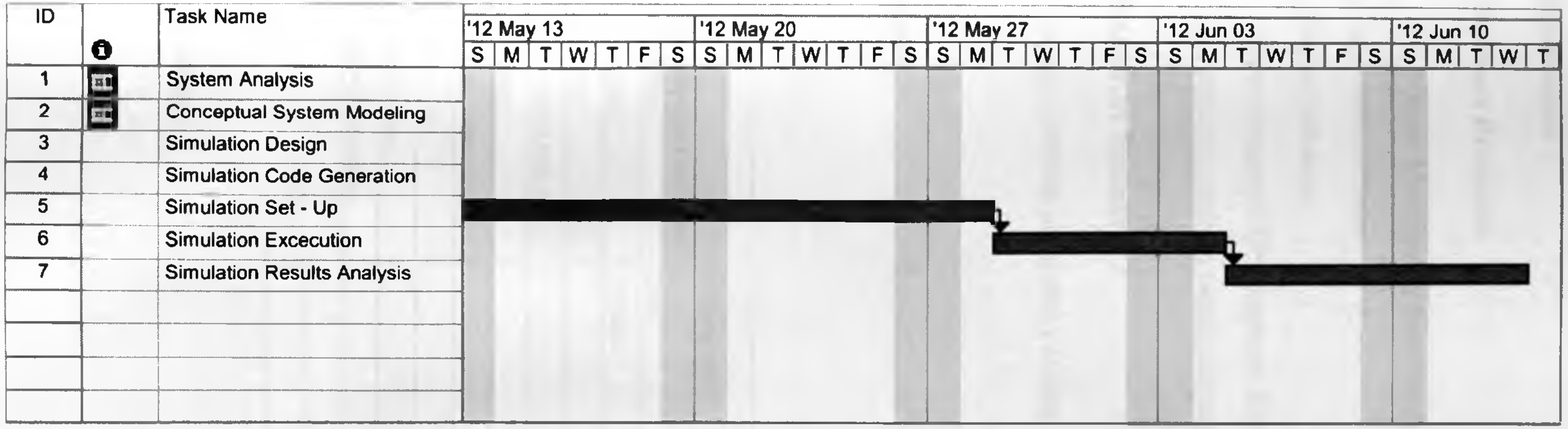


Figure 7-3. *Gantt Chart part 3.*

7.2 Requirements

7.2 .1 Software Resources

- Java Virtual Machine or Java Runtime Environment
- AnyLogic Software
- Repast Software
- Eclipse Integrated Development Environment
- Any operating system (windows preferred)

7.2 .2 Hardware Resources

- Laptop / desktop computer 2.0 Ghz. and above.

7.3 Budget

Name	Actual cost	Estimated cost	Variance	Total cost In Ksh.
Anylogic professional software Evaluation Edition	free	0.00	0.00	0.00
Computer (laptop)	50 000	50 000	0.00	50000.00
System Analysis		20000.00		20000.00
Conceptual System Modeling		28000.00		18000.00
Simulation Design		24000.00		14000.00
Simulation Code Generation		3000.00		3000.00
Simulation Set - Up		10000.00		5000.00
Simulation Execution		6000.00		4000.00
Simulation Results Analysis		15000.00		5000.00
				119000.00

Table 7-2. *Budget 1*

8. References

1. Atkinson,C and Kühne,T 2003 . Model-driven development: A metamodeling foundation. *IEEE Software*, vol.20, no 5, pp.36-41.
2. Bond, AH and Gasser, L 1988. An Analysis of Problems and Research in DAI.
3. Chauhan, D 1997, JAFMAS: *A Java-based Agent Framework for Multiagent Systems Development and Implementation*, Thesis, ECECS Department, University of Cincinnati.
4. DeLoach, S A 2001. Analysis and Design using MaSE and agentTool. Proceedings of the 12th Midwest Artificial Intelligence and Cognitive Science Conference (MAICS)
5. Dimakis, N, Gelenbe, FA 2010.Distributed building evacuation simulator for smart emergency management, The Computer Journal vol. 53, no. 9, pp.1384–1400.
6. Fahy, RF & Proulx, G 2009. panic and human behaviour in fire. Proceedings of the 4th International Symposium on Human Behaviour in Fire Robinson College, Cambridge, pp, 1-13
7. Faratin, P, Jennings, NR, Buckle, P & Sierra, C 2000. Automated negotiation for provisioning virtual private networks using FIPA-compliant agents. Proceedings of the 5th International Conference on Practical Application of Intelligent Agents and Multi-Agent Systems, Manchester, UK, pp. 185–202.
8. Garro, A and Russo, W 2010. easyABMS: a domain-expert oriented methodology for Agent Based Modeling and Simulation, *Simulation Modelling Practice and Theory*, vol. 18, no.10, pp. 1453-1467.
9. Groner, NE 1998. people power in fire related human behaviour, National Fire Academy, Emmetsburg, pp. 8-43.
10. Gwynne, S & Galea, ER (2004). A Review of Methodologies and Critical Appraisal of Computer Models Used in the Simulation of Evacuation from the Built Environment. Bethesda, MD: Society of Fire Protection Engineers.
11. Jafari, M, Bakhadyrov, I & Maher, A 2003. Technological Advances in Evacuation Planning and Emergency Management: Current State of the Art, no. NJ 08854-8014, The State University Piscataway, Rutgers.

12. Kothari, CR 2004. *Research Methodology*, 2nd ed., New Age Int. Publishers Ltd, New Dehli.
13. Lesser, VR 1999. Cooperative Multiagent Systems: A Personal View of the State of the Art. To appear in IEEE Trans. Knowledge and Data Engineering, Jan.-Feb. Special Issue.
14. Macal,CM and North, MJ 2010. Tutorial on agent-based modelling and simulation, *Journal of Simulation* vol. 4, http://www.palgrave-journals.com/jos/journal/v4/n3/abs/jos20103a.html, accessed in 1 March 2012
15. Musse, SR and Thalmann, D 2001. Hierachical Model for Real Time Simulation of Virtual Human Crowds. *IEEE Transactions on Visualization and Computer Graphics*, vol. 7, no. 2, pp. 152-164.
16. Nguyen, QH, McKenzie, FD and Petty, MD 2005. Crowd Behavior Cognitive Model Architecture Design. In Proceedings of the 2005 Conference on Behavior Representation in Modeling and Simulation (BRIMS). 55-64.
17. North, MJ, Tatara, E, Collier, NT, Ozik, J (2007). Visual Agent-based Model Development with Repast Simphony, Proceedings of the Conference on Complex Interaction and Social Emergence, Argonne National Laboratory, IL USA.
18. Object Management Group Inc.2007. Unified Modeling Language (UML) Specification Version 2.1.2.k
19. Perros, H 2009. *Computer Simulation Techniques: The definitive introduction*, NC state university, North Carolina.
20. Proulx, G 2000. Strategies for Ensuring Appropriate Occupant Response to Fire Alarm Signals, *Construction Technology Update*, no.43, pp.1-6.
21. Robinson, S 2004. *simulation: the practice of model development and use*, Wiley publications, Chichester, UK.
22. Salamon, T 2011. *Design of Agent-Based Models: Developing Computer Simulations for a Better Understanding of Social Processes*, Bruckner Publishers, Musikwissenschaftlicher Verlag.

23. Shen,T and Chien,S 2005. an evacuation simulation model (esm) for building evaluation, *International Journal on Architectural Science*, vol. 6, no. 1, pp.15-30.
24. Shendarka, A,Vasudevan, K, Lee, S & Son, Y 2006. crowd simulation for emergency response using bdi agent based on virtual lit, Proceedings of the 2006 Winter Simulation Conference, University of Arizona, Tucson, AZ 85719, U.S.A .
25. SILAGHI, GC 2005. Software Engineering Approaches for Design of Multi-agent Systems, paper presented to Bolyai University Cluj-Napoca.
26. Sime, J 2001. Occupant response: Inputs to design, fire safety engineering and facilities management, Fire Safety Engineering, vol. 1, no.38, pp.14-18.
27. Sycara, KP 1998. Multiagent systems, Artificial Intelligence magazine, 8-9 March, pp. 5.
28. Turner, B A, 1995. The role of flexibility and improvisation in emergency response. In Natural risk and civil protection (Eds, Horlick-Jones, T, Amendola, A and Casale, R) E &F Spon, London, pp. 463-475.
29. U.S. General Services Administration. 2003 (Revised 2006). Growth, Efficiency, and Modernism. pp. 14–15. Retrieved March 2011.
30. Weiss, G 1999. *Multiagent Systems: A Modern Approach to Distributed Modern Approach to Artificial Intelligence*, MIT Press Publisher, London.
31. Wooldridge, M 2009. *An Introduction to MultiAgent Systems*, 2nd edn. John Wiley & Sons Publishers.

9. Appendix

Building	Height in meters	*Year completed*
Lonhro house	80	*1990*
Aniversary Towers	80	*1992*
Rahimtulla Tower	80	*1999*
New Central Bank Building	140	*2000*
Teleposta Towers	120	*2000*
I &M Bank Tower	99.1	*2001*

Table 9-1. *Buildings completed as at February 2011*

This table illustrated all commercial buildings that had been completed by February 2011, done by year and height.

KEY

CWT (Cumulative wait time)	This is a measure of the total amount of time that a person wastes in congestion
PET (Personal Evacuation Time)	This is a measure of the time each individual requires to evacuate.

Table 9-2. *Key*

<u>Sample code</u>

```
package theevacuationmodel;
import java.sql.Connection;
import java.sql.SQLException;

import java.util.ArrayList;
import java.util.Arrays;
import java.util.Calendar;
import java.util.Collection;
import java.util.Collections;
import java.util.Comparator;
import java.util.Currency;
import java.util.Date;
import java.util.Enumeration;
import java.util.HashMap;
import java.util.HashSet;
import java.util.Hashtable;
import java.util.Iterator;
import java.util.LinkedList;
import java.util.List;
import java.util.ListIterator;
import java.util.Locale;
```

```java
import java.util.Map;
import java.util.Random;
import java.util.Set;
import java.util.SortedMap;
import java.util.SortedSet;
import java.util.Stack;
import java.util.Timer;
import java.util.TreeMap;
import java.util.TreeSet;
import java.util.Vector;

import java.awt.Color;
import java.awt.Font;
import java.awt.Graphics2D;
import java.awt.geom.AffineTransform;

import static java.lang.Math.*;
import static com.xj.anylogic.engine.presentation.UtilitiesColor.*;
import static com.xj.anylogic.engine.presentation.UtilitiesDrawing.*;
import static com.xj.anylogic.engine.HyperArray.*;

import com.xj.anylogic.engine.*;
import com.xj.anylogic.engine.analysis.*;
import com.xj.anylogic.engine.connectivity.*;
import com.xj.anylogic.engine.connectivity.ResultSet;
import com.xj.anylogic.engine.connectivity.Statement;
import com.xj.anylogic.engine.presentation.*;

import java.awt.geom.Arc2D;

public class Main extends ActiveObject
{
  // Events

  public EventCondition fireevent = new EventCondition(this);
  public EventCondition fireevent1 = new EventCondition(this);
  public EventTimeout _AnalysisChart_autoUpdateEvent_xjal = new EventTimeout(this);

  @Override
  public String getNameOf( EventTimeout _e ) {
    if ( _e == _AnalysisChart_autoUpdateEvent_xjal ) return "AnalysisChart auto
update event";
    return super.getNameOf( _e );
  }

  @Override
  public int getModeOf( EventTimeout _e ) {
    if ( _e == _AnalysisChart_autoUpdateEvent_xjal ) return
EVENT_TIMEOUT_MODE_CYCLIC;
    return super.getModeOf( _e );
  }

  @Override
  public double getFirstOccurrenceTime( EventTimeout _e ) {
```

```
    if (
        _e == _AnalysisChart_autoUpdateEvent_xjal
      ) return getEngine().getStartTime();
    return super.getFirstOccurrenceTime( _e );
  }

  @Override
  public double evaluateTimeoutOf( EventTimeout _e ) {
    if ( _e == _AnalysisChart_autoUpdateEvent_xjal ) return
1
;
    return super.evaluateTimeoutOf( _e );
  }

  @Override
  public void executeActionOf( EventTimeout _e ) {
    if ( _e == _AnalysisChart_autoUpdateEvent_xjal ) {
      AnalysisChart.updateData();
      return;
    }
    super.executeActionOf( _e );
  }

  @Override
  public String getNameOf( EventCondition _e ) {
    if ( _e == fireevent ) return "fireevent";
    if ( _e == fireevent1 ) return "fireevent1";
    return super.getNameOf( _e );
  }

  @Override
  public boolean testConditionOf( EventCondition _e ) {

    if ( _e == fireevent) return
true
;
    if ( _e == fireevent1) return
false
;
    return super.testConditionOf( _e );
  }
```

The A* Algorithm

A* uses a heuristic (a "guess") to search nodes considered more likely to lead to the destination first, allowing us to often find the best path without having to search the entire map and making the algorithm much faster.

A* is based on the idea that each node has some cost associated with it. If the costs for all nodes are the same then the best path returned by A* will also be the shortest path but A* can easily allow us to add different costs to moving through each node.

A* creates two lists of nodes; a closed list containing all the nodes we have fully explored, and an open list containing all the nodes we are currently working on (the perimeter of our search). Each node will have 3 values associated with it; F, G, and H. Each node will also need to be aware of its parent so we can establish how we reached that node.

- G: - the exact cost to reach this node from the starting node.
- H: - the estimated (heuristic) cost to reach the destination from here.
- F = G + H

As the algorithm runs the F value of a node tells us how expensive we think it will be to reach our goal by way of that node.

Pseudo code describes the algorithm:

```
function A*(start,goal)
    closedset := the empty set    // The set of nodes already evaluated.
    openset := {start}    // The set of tentative nodes to be evaluated, initially containing the start
node
    came_from := the empty map    // The map of navigated nodes.
     g_score[start] := 0    // Cost from start along best known path.
    // Estimated total cost from start to goal through y.
    f_score[start] := g_score[start] + heuristic_cost_estimate(start, goal)
     while openset is not empty
        current := the node in openset having the lowest f_score[] value
        if current = goal
            return reconstruct_path(came_from, goal)
```

```
    remove current from openset
    add current to closedset
    for each neighbor in neighbor_nodes(current)
      if neighbor in closedset
        continue
      tentative_g_score := g_score[current] + dist_between(current,neighbor)
      if neighbor not in openset or tentative_g_score < g_score[neighbor]
        if neighbor not in openset
          add neighbor to openset
        came_from[neighbor] := current
        g_score[neighbor] := tentative_g_score
        f_score[neighbor] := g_score[neighbor] + heuristic_cost_estimate(neighbor, goal)
  return failure
function reconstruct_path(came_from, current_node)
  if came_from[current_node] is set
    p := reconstruct_path(came_from, came_from[current_node])
    return (p + current_node)
  else
    return current_node
```

Regression Analysis

Scenario 1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99731
R Square	0.994628
Adjusted R Square	0.992837
Standard Error	0.27152
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*

Regression	1	40.94957	40.94957	555.4502	0.000167
Residual	3	0.22117	0.073723		
Total	4	41.17074			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 9*
Intercept	29.3328	0.284773	103.0042	2.02E-06	28.42653	30.23907	28.42653	30.2
X Variable 1	2.0236	0.085862	23.56799	0.000167	1.750348	2.296852	1.750348	2.29

ANOVA

	df	SS	MS	F	Significance F
Regression	1	114.5247	114.5247	82.41544	0.002824
Residual	3	4.168808	1.389603		
Total	4	118.6935			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	33.28745	1.236351	26.92396	0.000112	29.35283	37.22207	29.35283	37.22207
X Variable 1	3.38415	0.372774	9.078295	0.002824	2.197818	4.570482	2.197818	4.570482

Unguided

y=3.38415x+33.28

Guided

y=2.0236x+29.3328

Scenario 2

SUMMARY OUTPUT when guided

Regression Statistics	
Multiple R	0.977618912
R Square	0.955738737
Adjusted R Square	0.940984982
Standard Error	1.540461443
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	153.7228056	153.7228056	64.77936	0.004006
Residual	3	7.119064375	2.373021458		
Total	4	160.84187			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Uı 9:
Intercept	9.69125	1.615649592	5.998361308	0.00928	4.549532	14.83297	4.549532	14.8
X Variable 1	3.92075	0.487136681	8.048562455	0.004006	2.370464	5.471036	2.370464	5.47

SUMMARY OUTPUT without guidence

Regression Statistics	
Multiple R	0.985077185
R Square	0.970377061
Adjusted R Square	0.960502748
Standard Error	2.673891562
Observations	5

ANOVA

	df	SS	MS	F	Significance F
Regression	1	702.6211506	702.6211506	98.27287	0.002183
Residual	3	21.44908826	7.149696088		
Total	4	724.0702389			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Uppe 95.0
Intercept	6.632416667	2.80440113	2.365002851	0.09895	-2.29244	15.55727	-2.29244	15.557
X Variable 1	8.38225	0.845558755	9.913267347	0.002183	5.691305	11.0732	5.691305	11.07

Guided

y= 3.92075x+9.69125

not guided

y=8.38225x+6.632416667