MASTER THESIS PROJECT

A FRAMEWORK ON THE SECOND DISASTER REDUCTION NORM (NRD-2): MINIMUM SAFETY ASPECTS FOR PUBLIC BUILDINGS IN GUATEMALA

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April 27, 2012

In collaboration with the National Disaster Management Agency (CONRED) and the Guatemalan Association for Structural and Seismical Engineering

Coordinadora Nacional
para la Reducción de Desastres -CONRED-

CONSTRUCTION MANAGEMENT AND ENGINEERING - CME

A FRAMEWORK ON THE SECOND DISASTER REDUCTION NORM (NRD-2) MINIMUM SAFETY MEASURES FOR PUBLIC BUILDINGS IN GUATEMALA

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PREFACE

The construction of buildings has progressed over the centuries from stone buildings to the steel and concrete structures to the industrial revolution and technology today. People have an expectation that when they enter a building, it has been constructed in such a manner that if an emergency situation occurs in the building they will be safe and protected. As new building practices improve and new building technologies are developed, the complexity of the buildings has increased. As these complexities increase, building regulations must keep up with the technology. The codes adopted by governmental agencies and/or municipalities should not prohibit or limit the use of new materials or technologies. However, buildings must be constructed to be safe for the occupants. Therefore, the building code or national norms approved and validated have to keep up with the complex building practices and has become a complex document in itself.[1]

Whenever an emergency situation happens in a building, it is important to evacuate people in a safe and efficient manner. The design of a building must enable people to exit the and reach a safe place based on the hazards that might be present based on the occupancy classification. In institutional occupancies, it may not be possible or desirable to get occupants out. Therefore, the patients or prisoners are moved to other portions of the building that are protected from the hazard. In some cases, the hazards may be the material in the building and in others; it may be the number of people in the building. No matter what the situation is people within the facility must be kept safe.[2]

Building codes are sets of regulations adopted by governmental agencies and municipalities to ensure that buildings are built in a safe manner. People have an expectation that when they enter a building they will be safe from inherent dangers caused by natural or man-made disasters. One expects that if a storm passes through the building will keep the users dry and withstand the forces created by the storm such as wind. When the earth shakes in an earthquake, one expects the building to resist the forces and stay standing to a point that the building can be evacuated. When a fire occurs in a building, the occupants need a safe and expedient way out of the building. Building codes provide these protections by limiting the potential hazards in a building and requiring certain design requirements to provide the occupants with a safe environment in which to live and work.

On this thesis research project the subject of safety within public buildings and safety codes in Guatemala is the main topic of discussion. Guatemala is located in Central America, south of Mexico, over and between three tectonic plates and right in the path of tropical storms, volcanic eruptions and hurricanes. This means that the country sees its fair share of natural disasters every year. Main infrastructures as well as public buildings and private homes suffer from seismic events, flooding and landslides. But the fact these events happen does not come as a surprise to the authorities, but the fact that still year after year many lives are lost.

The safety and well being of the people is the main objective of the National Disaster Management Agency of Guatemala. They are the government branch in charge of overseeing all natural and man-made disasters and their impact on the population. Their

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[1] *Thomas 2009, Building Code Basics: Building, pg ix*
[2] *Thomas, 2009, Getting People Out, pp 88*

group of experts constantly monitors rivers and mountains to better inform the population of any harm an increase on the water level or a shift on the earth might have on them.

Monitoring wins only half the battle since no good comes out on being able to see when there is a potential danger if people cannot be put away from harms way. To do so, it is necessary to count with stable infrastructures and safe buildings. The safety within these buildings is the main topic of conversation within this thesis project. Public buildings in Guatemala even though built under strict international codes and regulation cannot be held accountable in case anything goes wrong since no Guatemalan legislation exists for this.

Guatemala, until last year didn't have a national building code. The conceptual design is taken care by architects and owners. In very special cases engineers are taken into account. So, the engineer has to deal with a design and accommodate different norms depending on what the architects and owners require. Every engineer in charge of constructing a building would base their calculations using other well-known codes such as the International Building Code and modify it in order to accommodate the situational needs. This makes it very difficult for the authorities to monitor and inspect the implementation of such code since it might be different for each building.

Last year, for the first time, nine regulations were passed as part of the first Disaster Reduction Norm (NRD-1). This norm holds the structural aspects and specifics on how buildings should be built and specifies the way they should be constructed with regards to their size, materials and occupancy classification.

The following step was to develop the second disaster reduction norm (NRD-2), which would encompass all the necessary topics in order to make the building a safe one. This norm would include topics for the design of emergency exits, evacuation routes, signaling and other safety aspects. The objective of this norm would be to ensure the safe evacuation of those inside the building during the events of an emergency.

This thesis project will lead the reader through the process of the development of this norm as well as its application in order to secure the safety of public building users in Guatemala. As an engineer, my responsibility is to the people and the development of the national building code and creating it is a step in the right direction. For that I am very proud and honored to have been able to form part of this process.

SUMMARY

By definition a building code "is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and non-building structures. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate authority."

As the previous statement defines, a building code must conform the central part of any construction project. It is accustom for every country to have its own set of rules that make out to be the national building code, since they are written to accommodate the special building conditions of that country. Nonetheless, countries such as Guatemala, considered as third world countries do not have a national building code by which to abide by. Instead, professionals from Guatemala have adopted several existing codes from other places such as the United States and Europe.

Adopting existing building codes from other places does not mean that the constructions in Guatemala are done in a poor and unsafe way. Nonetheless, this poses a threat to the owners as well as the users of the facilities, in the sense that if something would happen there is no way of proving the wrongdoing since there is not a specific set of rules and norms that are backed up by the law.

For this reason, a private national entity known as the Guatemalan Association of Structural and Seismical Engineers (AGIES) has worked to create a set of Guatemalan Norms for Structural Safety to form part of the National Building Code. Their work has presented results in the way of the creation of seven norms that encompass all the different building styles and their application in the Guatemalan territory.

Last year, AGIES formed an agreement and signed an agreement with the National Disaster Management Agency of Guatemala (CONRED) in order to continue with the development of these norms as well as their implementation. By March of 2011, the first Disaster Reduction Norm was legally passed in Guatemala, and it is made up by all seven structural safety norms previously made by AGIES. This agreement is the gateway to the creation of a set of norms for structural safety that could convey in the future for a Guatemalan National Building Code.

In this thesis, the development of the second Disaster Reduction Norm has taken place (NRD-2: Minimum Safety Measures for Public Buildings in Guatemala). The process to do this meant a lot of brainstorming in order to determine the safety elements that needed to be addressed on the NRD-2. To find this safety elements it was not only a matter of looking into existing building codes and selecting the criteria that best applied to Guatemala but also understand its importance under the Guatemalan context. For this reason the evaluation of certain scenarios took place and a section is devoted to this subject.

Once the assessment criteria or safety elements were selected, the development of the NRD-2 took place using common sense and experience as the main driving factors. Developing the NRD-2 was only half the battle; the purpose of such norm is to state the necessary elements a public building has to have in order to be considered safe. Therefore, showing the application of this norm is very important in order to fully

understand its extent. Section seven of this paper clearly describes the application of the norm in two simple examples. Having developed the NRD-2 it was necessary to create a form of evaluation in order to assess whether or not existing buildings are in accordance with what the normative states. For that, section eight of this research paper is focused on that evaluation. Finally from an engineering stand point an evacuation analysis took place where different factors that influence the evacuation of a space during an emergency such as the number of people, doors and the influence of a panic factor where evaluated.

Guatemala is in vital need to hold its own national building code, in order to secure not only the development of the construction industry but the overall safety and safeguard of the national public. By means of this thesis it is hoped to give the reader a better understanding of the framework for the development of a national Building Code for Guatemala and specifically with regards to safety aspects in the construction of public buildings.

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Part A: INTRODUCTION

This graduation research is a compulsory part in order to fulfill the graduation requirements of the M.Sc. program of Construction Management and Engineering (CME) at Delft University of Technology. In order to form a connection between the program and the practice environment, this research was executed in collaboration with the Guatemalan Association of Structural and Seismical Engineering. This association specializes in the development of civil engineering codes to be used in Guatemala. This research then looks into the development of safety regulations for buildings of public use within the Guatemalan territory.

1 INTRODUCTION

1.1 Overview

Guatemala like many other countries in Latin America is considered as a third world country and has many limitations when it comes to the construction industry. These limitations are specifically found in the national building codes or lack there off. The construction industry in Guatemala has always adopted international building codes but has never really followed a specific national code, one that applies directly to the building conditions of the country but rather modifies the norms that are used in other places of the world such as the United States and Europe.

A private national entity known as the Guatemalan Association of Structural and Seismical Engineering (AGIES for its name in Spanish: "Asociacion Guatemalteca de Ingenieria Estructural y Sismica") has strived since 1996 to create and implement a National Building Code. One that lists and explains every element of construction as well as safety aspects which apply directly to the building conditions of the country. The group of engineers that form the AGIES committee has created and passed seven structural safety norms (NSE in the Spanish language "Normas de Seguridad Estructural"), them being:

a. NSE 1: General Aspects of Design and Construction;
b. NSE 2: Structural Demands, Site Conditions and Protection Levels;
c. NSE 3: Structural Design for Buildings;
d. NSE 4: Prescriptive Requisites for Minor Dwellings and Structures of One or Two Levels;
e. NSE 5: Design Requisites for Infrastructure and Special Projects;
f. NSE 6: Design Requirements for Existing Buildings: Risk Reduction, Evaluation and Rehabilitation;
g. NSE 7: Reinforced Masonry

Nonetheless, the passing of these norms to become the law has proven to be a very difficult task. For these norms to be specifically used and followed they need to be backed up by the Government and adopted by the municipalities in order to become the Guatemalan Normative for Structural Safety National Building Code. To solve this problem, AGIES has formed an agreement with the National Disaster Management Agency of Guatemala, the governmental branch in charge of overlooking all aspects of the well being of the population with regards to natural or man-made disasters.

AGIES aims to promote and encourage scientific and technological research in the field of Structural Engineering and Seismology. One of its main goals is to promote and ensure the maintenance of Structural Safety Standards for the Republic of Guatemala, as well as promote the use of technical regulations for the structural design, for the purpose of producing works of safe and affordable engineering.

The cooperation between these two entities has proven to be effective since, in March of 2011 the first Norm for the Reduction of Disasters was legally passed; known as the NRD-1 – Structural Requirements for Critical, Essential and Important Construction Projects, and it encompasses all of the seven norms previously developed by AGIES.

The seven norms for structural safety developed by AGIES are specifically made to state the way a construction project should be build. But none of them deliver an explanation with regards to safety issues that go beyond the main building structure. For this matter, the continuation and development of other norms is necessary. AGIES together with the National Disaster Management Agency have come up with four other norms that need to be developed. These norms are:

a. NRD-2- Minimum Safety Measures for Public Buildings
b. NRD-3- Requirements for Concentrating Public Events
c. NRD-4- Fire Protection
d. NRD-5- Handling, transportation and storage of Hazardous Materials

1.2 Problem Definition

As previously stated, Guatemala like many third world countries does not count with a National Building Code or National Norms for Structural Safety to abide by, which means that engineers have adopted already existing codes from other parts of the world. Nonetheless, this poses big problems since the adopted norms are not validated by the national law, which makes it very difficult to evaluate and corroborate their good implementation. To battle this, an entity with the objective of creating a national building code was formed by Guatemalan engineers in 1996 and has recently formed an agreement with the National Disaster Management Agency who has governmental power with hopes of passing the already existing building norms as law and develop other important ones.

1.3 Overall Objectives of this Research

The main objective of the research underlying this master thesis is:

A framework for the development, application and evaluation of the Second Disaster Reduction Norm for Public buildings and its importance with regards to safety against Natural Hazards in Guatemala.

The following are the secondary objectives for this research:

- To work alongside the members of AGIES in the development of the NRD-2: Minimum Safety Measures for Public Buildings.
- To show the importance of this norm and its application in new projects and existing buildings.
- To pave the way for the continuation and development of other norms.
- Demonstrate the application and evaluation form for the NRD-2.

1.4 Specific Aim

In order to comply with CME regulations I will not only focus on the normative from a civil engineering standpoint but will do so also under a risk and evaluation perspective. By means of scenarios the main aspects of safety will be evaluated and their importance within the normative with regards to the natural hazards of Guatemala. Also, an evaluation based on the creation of set norm will have to be developed in order for competent authorities to evaluate public buildings that have to comply with the NRD-2 and keep track of those evaluations on a database.

2 STRUCTURE OF THE RESEARCH

When refereeing to the structure of the research the focus will be on the selection of the scope for the research. In the case of this paper the investigation will take the form of a "theory-oriented research". This form of investigation is all about solving a problem encountered in the theory building process. There are two types of theory-oriented research, them being: theory development and theory testing. This investigation will follow the steps of a 'theory-developing research' since part of the already existing theory on the Guatemalan Norms for Structural Safety still needs to be developed.[3]

2.1 Research Framework

A research framework is an overview of the consecutive steps to take in the course of the research project. Its formulation starts by the definition of the objective of the research. In the case of this research: the formulation of a building evaluation according to the second disaster reduction norm NRD-2: Minimum Safety Measures for Public Buildings in Guatemala. It is then necessary to define how one intends to reach this result. This is accomplished by defining the research object which is the phenomenon one is studying and will be making statements about on the basis of the research project to be carried out. For this research paper the object is: Development, implementation and evaluation of the Second Disaster Norm (NRD-2): Minimum Safety Aspects for Public Buildings in Guatemala. Next the approach in relation to the research object is defined. This is done in the form of a research perspective which works as a pair of glasses one uses to approach the research object. The research perspective for this investigation will be the 'assessment of criteria/safety measures' in order to reach the desired goal of developing the NRD-2. The final but by no means the least important aspect of the research framework is the definition of the activities that have to take place in order to arrive at the research perspective. In this case they are: Building code theory, conjunction and agreements with AGIES and Conjunction and agreements with CONRED .[4]

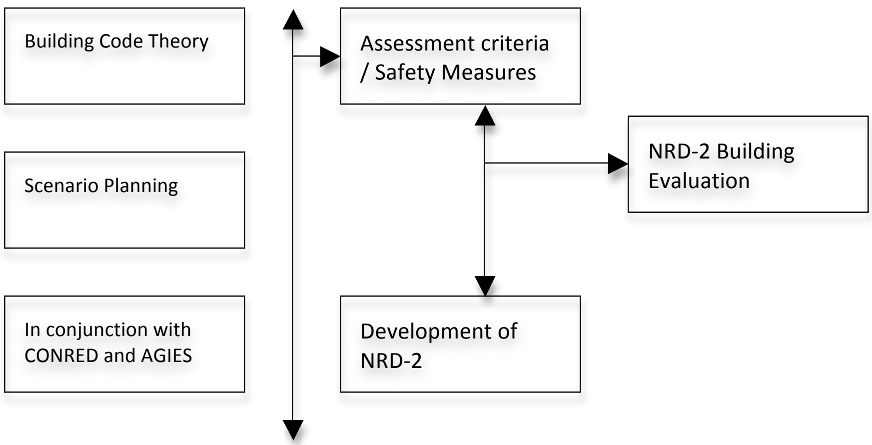

Figure 1. Research Framework NRD-2

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[3] *Verschuren and Doorewaard, 2005, Theory-oriented research, pp33-35*
[4] *Verschuren and Doorewaard 2005, Constructing a research framework, pp47-49*

2.2 Research Questions

1. Why are building codes important and how do they come about their existence?
    a. What is the Objective of having a norm that stipulates the minimum safety measures for public buildings?
    b. Is it necessary to adopt this norm by a municipality authority?
    c. Why is AGIES and not the National Disaster Management Agency who realized the proposal for this norm?
    d. What is the role of the Disaster Management Agency in the process of establishing the norm?
2. What are all the elements and criteria a construction project or existing building should contemplate according to the NRD-2.
    a. What Natural Hazards does Guatemala encounter that can influence the aspects evaluated by the disaster reduction norm?
    b. By means of scenarios what elements/criteria for the assessment of the disaster reduction norm need to be evaluated?
3. What is the analysis that should go behind the application of this norm in existing public buildings?
    a. In what ways will the application of this norm take place?
    b. How will the application of this norm be evaluated?

2.3 Outline of this Thesis

The content of this master dissertation is as follows:

Part A: Introduction

Part A will consist of the introduction to this master thesis and problem definition; it will include chapters 1 and 2.

Part B: Building Code Theory and Natural Hazards in Guatemala

Chapter 3 will give more detail on the background of building codes. This chapter is concerned with the question on why building codes are important and how do they come about their existence. This chapter forms part of the theoretical framework of this research.

Chapter 4 provides a theoretical background on the different natural hazards Guatemala has. This chapter will provide the necessary information in order to create scenarios that will demonstrate the importance of the Second Disaster Norm.

Part C: Stakeholder Analysis

Chapter 5 will focus on the parties involved in the process of developing the second disaster norm for Guatemala, and those who are affected by it. For this a stakeholder analysis will take place in order to show all involved parties and their influence on the project.

Part D: Scenarios

As mentioned before by means of the theoretical background described in chapter 5 with regards to natural hazards in Guatemala Chapter 6 will consist of the development of several scenarios that will demonstrate the need for the application of the Second Disaster Norm.

Part E: Minimum Safety Aspects for Public Buildings in Guatemala

Chapter 7 will describe the different assessment criteria that are involved in order to develop the Second Disaster Norm. This assessment criteria where obtained by means of evaluating other existing building codes and researching the needs of Guatemala's constructions with regards to the natural hazards they may encounter.

Chapter 8 will demonstrate the application of the Second Disaster Norm by means of two examples where an auditorium and a mall will be evaluated and put to the test to see whether or not the design complies with what is stated by the norm.

In chapter 9 an evacuation analysis is made in order to demonstrate the dynamics that goes on during an evacuation and the implications different variables have on the output.

Furthermore, it is necessary to form an evaluation format in order to verify if existing buildings as well as new constructions follow the safety measures stated on the Second Disaster Norm with regards to the buildings design. For this an evaluation format will be developed and explained in chapter 10.

Part F: Single Case Study

A single case is evaluated (chapter 11) in order to conclude this thesis. The case studied has to do with a fire that ignited in an Expo Center in Guatemala. By means of the safety assessment criteria for the NRD-2 the area is evaluated in order to determine whether or not it complies with set norm.

Conclusions and Recommendations

Finally chapter 12 contains overall conclusions of this study as well as recommendations for future research based on the results obtained.

In figure 2, an overview of the outline of this thesis is given as well as the relation between chapters is shown.

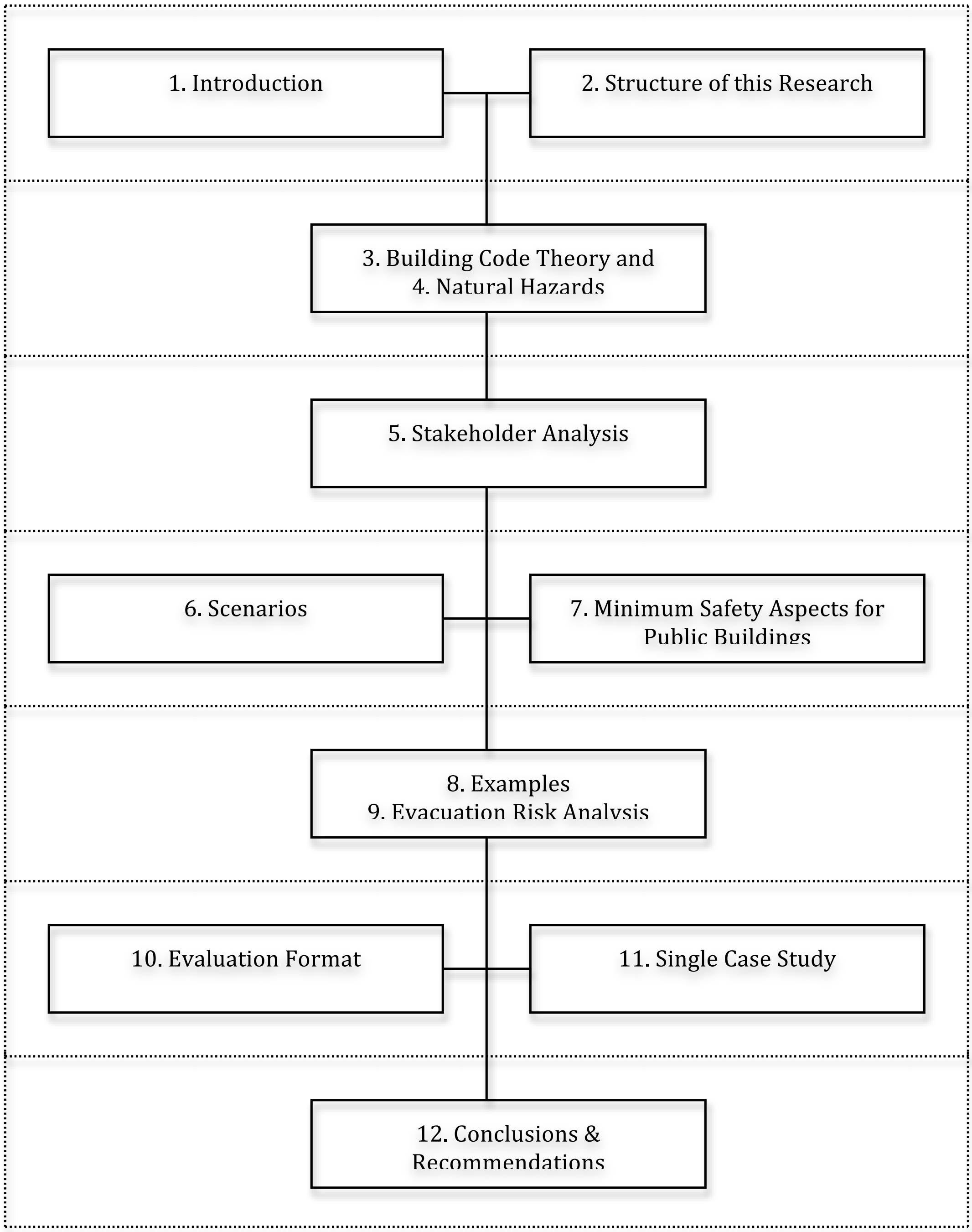

Figure 2. Outline of the thesis

Part B: **THEORY**

Building Codes are an essential part to all civil engineering projects. They regulate the process in which a project should be constructed and therefore ensure the well being of the users. Without building codes it is difficult to evaluate the well execution of such projects. Building codes are made out of different rules that touch upon all aspects of a construction project.

The main focus of this thesis is with regards to the development and implementation of one particular rule within the Guatemalan National Building Code. The Second Disaster Reduction Norm (NRD-2): Minimum Safety Measures for Public Buildings in Guatemala. This chapter touches upon the theory of building codes and existing natural hazards in Guatemala. It will pave the way for the following chapters where the importance of this new rule as well as its implementation will be explained.

3 BUILDING CODES

3.1 Building Code History

A building code is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and non-building structures. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally adopted and enacted by the appropriate authority.[5]

Building codes have been around for ages. The first known building code was found in the Code of Hammurabi, created about 1760 BC in ancient Babylon. This code, enacted by the sixth Babylonian king Hammurabi, set forth six rules for construction:[6]

- 228. If a builder has built a house for a man, and finished it, he shall pay him a fee of two shekels of silver, for each SAR built on.
- 229. If a builder has built a house for a man, and has not made his work sound, and the house he built has fallen, and caused the death of its owner, the builder shall be put to death.
- 230. If it is the owner's son that is killed, the builder's son shall be put to death.
- 231. If it is the slave of the owner that is killed, the builder shall give slave for slave to the owner of the house.
- 232. If he has caused the loss of goods, he shall render back whatever he has destroyed. Moreover, because he did not make sound the house he built, and it fell, at his won cost he shall rebuild the house that fell.
- 233. If a builder has built a house for a man, and has not keyed his work, and the wall has fallen, that builder shall make that wall firm at his own expense.

The Babylonian building code made great emphasis on the importance of a job well done by the builder and it stated the consequences if otherwise. Therefore it can be seen as the oldest liability claim.

Architects and engineers generally apply building codes and norms although this might not always be the case. Building codes may also be used for various purposes by safety inspectors, environmental scientists, real estate developers, contractors and subcontractors, manufacturers of building products and materials, insurance companies, facility managers, tenants and others; basically anybody who has something to do with the building in question will have something to do with the building code used upon it.[7]

The practice of developing, approving and enforcing building codes varies considerably among nations. In some countries building codes are developed by the government agencies or quasi-governmental standards organizations and then enforced across the country by the central government. Such codes are known as the National Building Codes since in a sense they enjoy a mandatory nation-wide application.

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[5] *Building Codes, 2011, http://en.wikipedia.org/wiki/Building_code*
[6] *Thomas, 2009, History of Codes, pp 3*
[7] *Building Codes, 2011, http://en.wikipedia.org/wiki/Building_code*

3.2 The Importance of Building Codes

Building codes regulate building construction and use in order to protect the safety and health of occupants. Codes address structural integrity, fire resistance, safe exits, lighting, and ventilation and they also regulate construction materials. Building codes classify structures by use and apply different standards to each classification. For example, office buildings (public domain) and residential multi-unit buildings (private domain) are in separate categories with different performance requirements. (FEMA, 1998)

Building codes have existed in North America since the seventeenth century. The earliest building regulations addressed problems resulting from dense urban construction, such as the rapid spread of fire. The Triangle Factory Fire (Ney York City) from 1911 demonstrated the importance of well-established safety measures within public buildings. There would not be such a devastating disaster as this one until the collapse of the World Trade Center 90 years later.

> "The Triangle Waist Company Factory occupied the eight, ninth and tenth floors of a 10-story building located in the Greenwich Village area of New York City. The factory produced women's blouses known as "shirtwaists". The factory normally employed about 500 workers, mostly young immigrant women. As the workday was ending on the afternoon of Saturday, March 25, 1911, a fire flared up at approximately 4:40 PM in a scarp bin under one of the cutter's tables on the eighth floor."
>
> "A bookkeeper on the eighth floor was able to warn employees on the tenth floor via telephone, but there was no audible alarm and no way to contact staff on the ninth floor. Although the floor had a number of exits, - two freight elevators, a fire escape and stairway down to the street, flames prevented workers from descending. The door leading to one of the stairways was locked to prevent theft by the workers; the locked doors allowed managers to check the women's purses and the foreman who held the stairway key had already escaped by another route. There was a single exterior fire escape, a flimsy and poorly anchored iron structure that may have been broken before the fire. It soon twisted and collapsed from the heat and overload, spilling victims nearly 30 meters to their deaths. Also, the emergency fire hoses within the building did not work. All in all 146 young immigrant workers lost their lives that day. Comprehensive building regulations were introduced and enforced after this disaster."[8]

Building codes are therefore important in order to safeguard building users from potential harms.

3.3 The Costs of Building Codes

[8] *The Triangle Factory Fire, http://www.ilr.cornell.edu/trianglefire/*

There are two costs associated with building codes. One is the cost of additional material and quality of workmanship, and the other is the cost of administration and enforcement. Criticism of the cost of building codes centered on the inefficiencies of having numerous codes, inconsistently applied. To address these issues, the National Commission on Urban Problems recommended more uniformity in building codes, including adoption of state building codes. By making a uniform building code it is possible to keep costs down and ensure the well being of building users.

3.4 Adopting a Building Code

For building codes to be successfully used they must be adopted by all states or municipalities of a country. This might appear to be a tough job but it should translate into a relatively easy process. States or local governments should adopt and entire model building code, one they should not have to make any changes to it or if so, these changes should be minor in order to accommodate the needs of that municipality. Model building codes save local governments the time and cost required to write an original code themselves. They include sections detailing the administrative procedures for plan review, building inspections, plan and building approval, and code enforcement.

3.5 Disaster Reduction Norm NRD-1 (Guatemala)

The NRD-1 is the result of a process that began in Guatemala in 1986 before a solicitation issued by the Ministry of Communications, Transport and Public Works (now known as the Ministry of Communications, Infrastructure and Housing), for the formulation of the RULES OF STRUCTURAL DESIGN AND CONSTRUCTION for the Republic of Guatemala, which ended drafted in 1988 without being able to publish. In 1994, the National Institute of Seismology, Vulcanology, Meteorology and Hydrology (INSIVUMEH) and the Special Committee reviewed the original project and tried to give an official and legal assistance to those standards, but this was not achieved.

Subsequently, the formation of the Guatemalan Association of Structural and Seismical Engineering (AGIES) in 1996 decided to give these standards a sustained effect on the technical consensus among its members and the general assembly decided to present the updated draft as a recommended standard. In 2001, with the support of the Executive Coordination Secretariat of the Presidency, worked on completing some norms which were published between 2000 and 2001.

In August 2007, the Ministry of Communications, Infrastructure and Housing issued by Ministerial Resolution No. 1686-2007 which established a committee of technical standardization and regulation to coordinate de development and updating of all the technical standards that are used, within which the adoption of the Recommended AGIES norms took place.

Finally, before all this effort, the National Disaster Management Agency saw the importance of issuing regulations that are of national enforcement, protected by Article 3 of the agency's rule book, giving birth then to the NRD-1.

The NRD-1 compiles all seven Structural Safety AGIES norms, but no longer are a mere recommendation but have become part of the country's legislation under the accordance number 03-2010 of the National Council for Disaster Reduction in its fifth article. The NRD-1 is made up by all of the following:

a. NSE 1: General Aspects of Design and Construction;
b. NSE 2: Structural Demands, Site Conditions and Protection Levels;

c. NSE 3: Structural Design for Buildings;
d. NSE 4: Prescriptive Requisites for Minor Dwellings and Structures of One or Two Levels;
e. NSE 5: Design Requisites for Infrastructure and Special Projects;
f. NSE 6: Design Requirements for Existing Buildings: Risk Reduction, Evaluation and Rehabilitation;
g. NSE 7: Reinforced Masonry

All of these building specifications have been made for specific types of construction projects that fall into three main categories, them being: critical, essential and important construction. These three categories try to encompass most if not all of the different types of construction works. In the following section, the classifications for the different construction types are described.

3.5.1 Construction Classification

In Guatemala, all new or existing construction can be classified under one of five categories:

1. Critical
2. Essential
3. Important
4. New
5. Works in progress

3.5.1.1 Critical Constructions

Those essential for the socioeconomic development of large sectors of the population. Their failure or collapse would directly or indirectly endanger a large number of people. For example: the main components of large power plants, large size dams, large bridges, highways, roads and other similar structures.

3.5.1.2 Essential Constructions

These must remain operative during and after a disaster or adverse event. This category included public or private works. For example: Hospitals with emergency facilities, intensive care units and operating rooms. Civil defense facilities, fire, police and communications associated with disaster relief, power plants and related facilities, facilities for water collection and treatment, central telecommunication, power transmission trunk lines, water supply lines, bridges on first degree roads and other works that the state or municipality specify as such.

3.5.1.3 Important Constructions

Those that house or can involve large numbers of people, where the occupants are restricted to move, provide important services (but not essential after a disaster) to large numbers of people or entities, works that harbor recognized cultural values or high cost equipment belong to this category.

For example: State works and public buildings that are not essential, educational buildings and public or private nurseries, all hospitals, sanatoriums and public or private health care centers that do not classify as essential constructions; emergency vehicle parking lots, prisons, museums and other of similar kind.

3.5.1.4 New Constructions

All new constructions must comply with the requirements of the NRD-1 norm. And it is forbidden to build in high-risk zones.

3.5.1.5 Works in Progress

All of these must be evaluated and modified if necessary so that they comply with the NRD-1 Norm.

3.6 Existing Building Codes

As mentioned before, several building codes do exist since most countries have created and use their own building code. Nonetheless there are some codes that hold a renowned spot not only on a national but also on and international level. These codes are the Uniform Building Code, which was later substituted by the International Building Code for the United States and the Eurocode for Europe.

3.6.1 Uniform Building Code

The Uniform Building Code (UBC) was a building code used primarily in the western United States. It was first published in 1927 by the International Council of Building Officials and it was intended to promote public safety and provide standardized requirements for safe construction which would not vary from city to city as had previously been the case. [9]

3.6.2 International Building Code

Due to the globalization by 1997 the International Code Council initiated an efford to have only one set of regulations instead of having several. That effor was culminated in 2000 when the new International Building Code (IBC) published by the International Code Council (ICC) replaced the UBC in 2000. The ICC was a merger of three predecessor organizations which published three different building codes. Them being, the International Council of Building Officials (ICBO) Uniform Building Code; the Building Officials and Code Administrators International (BOCA) The BOCA National Building Code; and the Southern Building Code Congress International (SBCCI) Standard Building Code.[10]

The new IBC was intended to provide consistent standards for safe construction and eliminate differences between the three different predecessor codes addressing the design and installation of building systems through requirements and emphasizing in performance. It is primarily used in North America.

The International Building Code (IBC) is a model building code developed by the International Code Council (ICC). It has been adopted throughout most of the United States. A large portion of the IBC deals with fire prevention. It differs from the related International Fire Code in that the IBC addresses fire prevention in regards to

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[9] *Uniform Building Code, 2011, http://en.wikipedia.org/wiki/Uniform_Building_Code*
[10] *Uniform Building Code, 2011, http://en.wikipedia.org/wiki/Uniform_Building_Code*

construction and design and the fire code addresses fire prevention in regards to the operation of a completed and occupied building. For example, the building code sets minimum criteria for the number, size and location of exists in the design of a building while the fire code requires the exists of a completed and occupied building to be unlocked. The IBC applies to all structures in areas where it is adopted, except for one and two family dwellings; these are referred too in the International Residential Code.[11]

The codebook itself (2000 edition) totals over 700 pages and chapters include:

- Building occupancy classifications
- Building heights and areas
- Interior finishes
- Foundation, wall and roof construction
- Fire protection systems (sprinkler system requirements and design)
- Materials used in construction
- Elevators and escalators
- Already existing structures
- Means of Egress

The phrase "means of egress" refers to the ability to exit the structure, on a continuous and unobstructed path of vertical and horizontal egress travel from any occupied portion of a building or structure to a public way, primarily in the event of an emergency evacuation, such as a fire or earthquake. Specifically, a means of egress is broken into three parts: the path of travel to an exit, the exit itself, and the exit discharge (the path to a safe area outside). The code also address the number of exits required for a structure based on its intended occupancy used and the number of people who could be in the place at one time as well as their relative locations. It also deals with special needs, such as hospitals, nursing homes, and prisons where evacuating people may have special requirements. In some instances, requirements are made based on possible hazards (such as industries) where flammable or toxic chemicals will be in use.[12]

The IBC as mentioned before, is one of the codes in the family of International Codes published by the International Code Council (ICC). All of these codes are maintained and updated through and open code-development process and are available internationally for adoption by the governing authority to provide consistent enforceable regulation for the building environment.

3.6.3 International Mechanical Code

The International Mechanical Code (IMC) has been developed to apply to the design, installation, maintenance, alteration, and inspection of permanent mechanical systems that are installed within buildings. This covers heating, ventilation, and air-conditioning systems that are incorporated into the buildings.[13]

3.6.4 International Plumbing Code

The International Plumbing Code (IPC) has been developed to fill the void in the IMC for fuel gas appliances. It regulates the design, installation, maintenance, alteration and

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[11] *International Bilding Code, 2011, http://en.wikipedia.org/wiki/International_Building_Code*

[12] *International Bilding Code, 2011, http://en.wikipedia.org/wiki/International_Building_Code*

[13] *Thomas, 2009, Construction Codes: Scope and Limitations, pp 5*

inspection of appliances that use natural gas and liquefied petroleum gas, gaseous hydrogen systems, and related accessories.[14]

3.6.5 International Energy Conservation Code

The International Energy Conservation Code (IECC) has been developed to regulate the energy use in buildings. This code provides requirements for insulation R-values and door and window insulation requirements, as well as air infiltration limitations. The IECC applies to all types of buildings that are either heated or cooled.[15]

3.6.6 International Fire Code

The International Fire Code (IFC) has been developed for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings and structures. It also provides regulations for the safety of firefighters and emergency responders during emergency operations.[16]

3.6.7 International Fuel Gas Code

The International Fuel Gas Code (IFGC) has been developed to fill the void in the IMC for fuel gas appliances. It regulates the design, installation, maintenance, alteration and inspection of appliances that utilize natural gas and liquefied petroleum (LP) gas, gaseous hydrogen systems and related accessories.

3.6.8 International Residential Code

The International Residential Code (IRC) regulates the construction of one and two-family dwellings, as well as townhouse structures. Nonetheless, these types of buildings are not covered in the scope of the IBC. The IRC is designed to be a completely stand-alone code for building, energy, mechanical, fuel gas, plumbing, and electrical into one document. This provides one source of regulation for homebuilders and jurisdictions. Although some requirements in the IRC are similar to the other ICC codes, it is a separate stand-alone code. It incorporates more prescriptive provisions for the construction of homes.

3.6.9 Eurocodes

Eurocodes are a set of pan-European model building codes, developed by the European Committee for Standardization. The Eurocodes form a common European set of structural design codes for civil engineering works and are intended to replace the existing national codes published by national standard bodies, although many countries will have a period of co-existence. Additionally, each country is expected to issue a National Annex to the Eurocodes which will need referencing for a particular country.

Eurocode 0: Basic structural design
Eurocode 1: Actions on structures
Eurocode 2: Design of concrete structures
Eurocode 3: Design of steel structures
Eurocode 4: Design of composite steel and concrete structures
Eurocode 5: Design of timber structures

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[14] *Thomas, 2009, Construction Codes: Scope and Limitations, pp 6*
[15] *Thomas, 2009, Construction Codes: Scope and Limitations, pp 6*
[16] *Thomas, 2009, Construction Codes: Scope and Limitations, pp 6*

Eurocode 6: Design of masonry structures
Eurocode 7: Geotechnical design
Eurocode 8: Design of structures for earthquake resistance
Eurocode 9: Design of aluminum structures

In the Netherlands the project of setting up the National Annexes to the Eurocodes is still in progress. It is also planned to translate the Eurocodes (together with Belgium) into Dutch. The project in the Netherlands is divided into 3 different parts:[17]

- Buildings: 20 subparts (varying between the Eurocodes). These were published at the beginning of 2008. Seven parts concern Eurocode 0 and Eurocode 1.
- Bridges: 15 subparts (under which all parts 2 of the Eurocoes). Five parts concern Eurocode 0 and Eurocode1. These are still in progress and are expected at the end of2010.
- Other: 20 subparts. This is still under consideration. For about 8 parts a calibration study will probably be carried out, after which a National Annex will be formulated (e.g.: Pipe lines (1993-4-3).

For the other parts, a standard National Annex will be introduced in which the recommended values will be adopted and the choices will be left to the private parties. The 'Bouwbesluit 2003' currently refers to the National Codes and in the foreword to the National Codes it is stated that a comparable level of safety should be obtained with the use of Codes.

It is planned that by January 1, 2012 the Eurocode will be fully implemented in the Netherlands as well as its expected references in the new Bouwbesluit. As of that moment the NEN code must be used for a brief period (probably 1 to 2 years). Of course it is not allowed to mix different codes in one project, this will not lead to the desired safety of a construction.

[17] *Eurocodes, Legal situation per country, 2010, http://www.eurocodes-online.com/index.php/en_US/en/about-the-eurocodes/legal-situation-per-country*

4 NATURAL HAZARDS IN GUATEMALA

Guatemala is a country that is revisited every year by several natural disasters, not only because these hazards exist but because Guatemala has become very vulnerable towards them, incapable of coming out of one disaster in time to face another. Guatemala's natural hazards range from landslides and debris-flows to volcanic activity, seismic hazards and forest fires, most of these if not all, occurring every year.

4.1 Landslides and Debris-flows

- **Hurricane Mitch (1998)**

  Hurricane Mitch was the most powerful hurricane and the most destructive of the 1998 Atlantic hurricane season, with maximum sustained winds of 285 km/h. Due to its slow motion from October 29 to November 3, Hurricane Mitch dropped historic amounts of rainfall in Guatemala with reports of up to 1900 mm. By the time Mitch made landfall, over 10,000 people were evacuated along the Guatemalan coastline, 260 death were directly accounted from the hurricane and damages came out to be of $748 million. The heavy rains brought by this hurricane caused mudslides and severe flooding, the flooding destroyed 6,000 houses and damaged 20,000 others, displacing over 730,000 and forcing over 100,000 to evacuate.[18]

- **Tropical Storm Stan (2005)**

  Stan was a relatively weak storm that only briefly reached hurricane status. It was embedded in a large non-tropical system of rainstorms that dropped torrential rains in Guatemala as well as other countries of Central America causing flooding and mudslides that led to 1,628 fatalities. By October 11, 2005 at least 1,500 people were confirmed to have died and up to 3,000 were believed missing. Many communities were overwhelmed and the worst single incident occurred in Panabaj where in the early morning hours of October 5, 2005 the town was flooded in a landslide triggered by torrential rains. Mud poured off the saturated slopes of the volcano that loomed over the village, burying people and buildings.[19]

- **Tropical Storm Agatha (2010)**

  Agatha made landfall near the Guatemalan-Mexico border on the evening of May 29 producing torrential rains across the country which resulted in the deaths of 152 people in Guatemala and 100 left missing by landslides. As of June 15, officials in Guatemala stated that a total of 165 people were killed and 113 were missing due to the storm. The Guatemalan President Alvaro Colóm said that he believed Agatha could wreak more damage in the country than Hurricane Mitch and Hurricane Stan. A total of 112,000 people were evacuated and at least 20,000 were left homeless as a result of the storm.[20]

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[18] *Hurricane Mitch, http://en.wikipedia.org/wiki/Hurricane_Mitch*
[19] *Hurricane Stan, http://en.wikipedia.org/wiki/Hurricane_Stan#Guatemala*
[20] *Tropical Storm Agatha, http://en.wikipedia.org/wiki/Tropical_Storm_Agatha_(2010)#Guatemala*

- **Rainy Season (2011)**

Every year Guatemala faces major disasters all throughout the rainy season which typically consists of the months of June till November. Sometimes these disasters are caused by hurricanes and tropical storms that hit the area and others are the results of typical rainfall on previously saturated terrains. Nonetheless the year 2011 has proven to be a devastating one when it comes to rain. Up to now (October 28, 2011) there have been reports of 34 people dying, 7 missing and 175,355 affected by means of landslides and flooding. [21]

Figure 3. Landslides and Debris Fall 2011

4.2 Volcanic Activity

- **Agua Volcano Flooding (1541)**

In 1541 a lahar at the volcano destroyed the original Guatemalan capital city, killing more than 600 people. Torrential rains caused the crater to flood and overflow, sending rivers of water in the direction of the [old] city.[22]

- **Pacaya Volcano Explosion (2010)**

On May 27, 2010 the Pacaya volcano erupted, followed by several tremors. At approximately 20:00 hours there was a stron eruption ejecting debris and ash columns up to 1,500 meters. Ash rained down in many Guatemalan cities including the capital. Heavy rain from Tropical Storm Agatha worsen the emergency situation, causing lahars, landslides and widespread flooding across the country. [23]

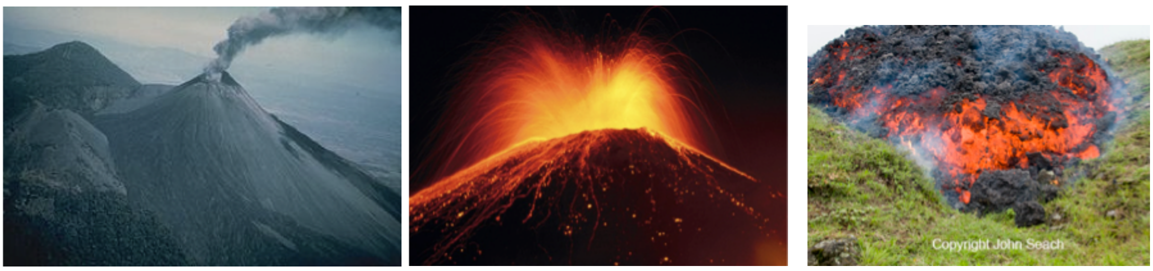

Figure 4. Pacaya Volcano Eruptions

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[21] *Estragos por Lluvias, 2011, http://www.prensalibre.com/especiales/estragos_lluvias/*
[22] *Agua Volcano, http://www.volcanolive.com/agua.html*
[23] *Pacaya Volcano May 2010 Eruption, http://en.wikipedia.org/wiki/Pacaya#May_2010_eruption*

4.3 Seismic Hazards

- **1976 Earthquake**

  The 1976 Guatemala earthquake struck on February 4 at 3:01 local time. It was a 7.5 magnitude earthquake, centered in the Motagua Fault, about 160 km northeast of Guatemala City. The earthquake struck during the early morning when most people were asleep. This contributed to the high death toll of 23,000.[24]

- **2011 Earthquake**

  Three earthqukes rocked Guatemala on Monday September 19, 2011. The U.S. Geological Survey (USGS) reported that a quake with a magnitude of 5.8 hit at 12:34 pm local time. Weaker quakes both measuring a magnitude of 4.8 struck about thirty minutes before and about forty five minutes after the larger tremor. One woman died in a landslide triggered by the earthquake. [25]

Figure 5. Earthquakes in Guatemala

4.4 Forest Fires (2011)

The Disaster Management Agency of Guatemala has reported that since the beginning of the year (2011) 199 forest fires have been registered, most of them located in the department of El Quiche in the northern part of the country. These fires have not claimed any lives and have all been fully controlled and put out.[26]

Figure 6. Forest Fire in Guatemala

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[24] *1976 Guatemala earthquake, http://en.wikipedia.org/wiki/1976_Guatemala_earthquake*

[25] *Magnitude 5.8 – GUATEMALA, USGS, http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0005wx9.php*

[26] *The Guatemalan Times, Guatemala: 199 forest fires recorded in 2011, April 2011, http://www.guatemala-times.com/news/guatemala/2236-guatemala-199-forest-fires-recorded-in-2011.html*

Part C: **STAKEHOLDER ANALYSIS**

It is important to recognize the relevant parties involved in the development and application of the NRD-2. For that this chapter will show the different stakeholders and their interests with regards to this project. Their interests as well as their connection to the project will be evaluated and explained in order to better inform the reader of the people involved and touched upon the development of this norm.

5 PARTIES INVOLVED

A stakeholder can be defined as anybody who has an interest in the project, its work, outputs, outcomes and ultimate goals. Stakeholders are those individuals or groups that are likely to affect or be affected by a proposed action, and sorting them according to their impact on the action and the impact the action will have on them is explored by means of a stakeholder analysis.

With regards to the development of the second disaster norm in hopes of eventually completing the Guatemalan National Building Code different actors are involved in the process. These actors and their interests as well as their influence on the process will be analyzed in this section. The following are the potential stakeholders for this project; their interests have been summarized in the stakeholder registry on table 1.

- ***Disaster Management Agency - CONRED:*** This government-based entity in charge of looking after the well being of the population with regards to natural and man-made disasters was in charge of developing the Second Disaster Norm - NRD-2 and must ensure its implementation. By means of developing this norm, public building users will be protected against any harm the building might have upon them. The agency will too be capable of evaluating new as well as existing structures in order to verify whether or not they comply with what the NRD-2 specifies. By means of this norm, lead institutions, owners, architects and engineers can be held accountable in case of a poor implementation of such norm.

- ***Guatemalan Association of Structural and Seismical Engineering (AGIES):*** A private national entity formed in 1996 with the specific goal of creating the Guatemalan National Building Code. Members of AGIES include engineers from different fields such as structural, civil and material engineering. Together they have come up with seven norms that have to do with all structural elements, materials and methods for Guatemalan constructions. Since forming an agreement with CONRED these structural building norms have been approved by congress and have become the First Disaster Reduction Norm (NRD-1) of the Guatemalan National Building Code. They are now working on passing the NRD-2 and subsequently other norms that will follow.

- ***Congress*** is in charge of passing or denying new laws for the country. In the case of the NRD-2, it is they who will have to approve it in order for it to become law and form part of the National Building Code. If it is approved, the NRD-2 becomes part of the country's jurisdiction and will have to be followed by all those affected by it. If this is not the case those who breach it will suffer legal consequences.

- ***Local Government / Municipalities:*** Guatemala is divided into departments, each of which has its own Municipality lead by its local government. This entity is in charge of overseeing all government related activities from that sector and is directly linked to the national government. Therefore, local governments are in charge of approving new constructions to be done within its governing limits. In order for the NRD-2 to be a success it has to be accepted by the municipalities as well. They will be the entity in charge of enforcing this rule.

- ***Responsible Lead Institutions***: They are those government-based institutions responsible of overseeing the functionality of some public buildings. For example, the Ministry of Education is considered to be the responsible lead institution for all buildings being used as schools, universities and classrooms. The Ministry of Health is the responsible entity over all Hospitals and public clinics. This lead institutions must then ensure that all of these existing buildings follow the safety measures stated by the NRD-2, if they don't the necessary adjustments to the buildings must take place in order for them to continue operating as such. Failure to comply will lead to fines and potential closure of the facilities.

- ***Public Facility owners***: A public facility owner is the person or group of people who own the structural space that holds public activities. Whether it is a stadium, commercial mall or office building, this person or group of people must ensure that the building complies with what is stated on the NRD-2 in order to guarantee the safety of the users. If this is not the case, they can be held accountable in the events of a disaster.

- ***Architects/Engineers***: In order for an architectural design to be accepted it will have to comply with all safety aspects addressed on the NRD-2. Architects and engineers will have to abide by this normative to make their constructions the safest they can be else the design will be rejected.

- ***Public Facility users:*** These are the people that will be using the public facilities that need to comply with the NRD-2. The users safety is at stake in case of the occurrence of a natural or man-made disaster that puts their lives at risk. The good implementation of such norm will make the difference between saving or potentially loosing lives.

Table 1 summarizes the previously mentioned stakeholders as well as their interests with regards to this project, whether they are against or for the realization of the project and the communication strategy used with each in order to keep them informed is summarized on the table as well. The National Disaster Management Agency is the main stakeholder since it is they, together with AGIES that want the NRD-2 to become part of the National Building Code. It is them who have worked on developing the norm in order to guarantee the well being of public building users against natural and man-made disasters. Its influence towards the project is a high one but this is redundant since it is them who first proposed the realization of such project which means they are informed at all times and are therefore in charge of all briefings that are given to keep other stakeholders informed as well.

AGIES's main objective is to develop the Guatemalan National Building Code and since the NRD-2 will be part of this code they have to be involved all throughout its development. Like CONRED, they are completely for the realization of the project and too hold high influence towards the project since the group of engineers that form AGIES are the ones in charge of writing the code. They are at all times informed of the projects development and can give and receive opinions on the matter to CONRED.

All local governments and municipalities will be the ones in charge of applying and overseeing the well implementation of the norm on existing and new public constructions within their jurisdiction. They are considered impartial toward the realization of such project since they have no control on the development and passing of new laws of the country they merely follow the law.

SECOND DISASTER REDUCTION NORM (NRD-2)
STAKEHOLDER REGISTRY

Stakeholder	Objectives	For/against	Influence	Informed	Communication Strategy
Disaster Management Agency (CONRED)	Develop the NRD-2 in order to guarantee the well being of public building users.	For	High	Must be	In charge of briefings
AGIES	Develop the Guatemalan National Building Code	For	High	Must be	Regular briefings Seek opinions
Congress	Approval or not of the NRD-2 in order to become law	For or Against	High	Must be	Regular briefings
Local Government / Municipalities	Oversee the implementation of the NRD-2 in the design of new public buildings. Evaluate existing buildings to see if they comply with what is specified in the NRD-2 Oversee the necessary changes existing buildings have to make in order to comply with NRD-2	Impartial	Medium	Must be	Regular briefings Seek opinions
Responsible Lead Institutions	To comply with what is stated on the NRD-2 with regards to existing and new constructions of public use that are under their	Impartial	Low	Must be	Regular briefings

	jurisdiction.				
Public Facility Owner	To comply with what is stated on the NRD-2 with regards to existing and new constructions of public use that are under their ownership.	Impartial	Low	Not at start	Consultations
Architects/Engineers	To follow what is stated by the NRD-2 in the design and construction of new public buildings and remodeling of existing buildings.	Impartial	Low	Not at start	Open Channels
Public Facility Users	To be safe when inside a public building.	For	Low	Not at start	Open channels

Table 1. Stakeholder Registry

On the other hand Congress is a very important stakeholder since they do hold the power to pass or deny new laws. Their main objective is to oversee the passing of new laws in the country in order to benefit the well being of the nation. In the case of this project, in order for the NRD-2 to hold legal substance it has to first be approved by Congress. The influence they have towards the project is very high and they must be informed at all times through the development of the norm.

All lead institutions like local governments will have to follow the norm once it is passed as law and becomes part of the national building code. They will have to ensure its implementation and evaluate all existing building in order for them to comply with such norm. if this is not the case they will suffer legal consequences that will cost them a lot of money and potential facility closure. Therefore they are impartial to the project since they have no direct influence on its realization. Public facility owners fall under this same category.

Every new construction will be design by an architect or engineer who will have to follow the safety regulations stated within the NRD-2 in order for the design to be accepted and developed as a new project. Therefore they are also impartial to the realization of such project since they have no influence towards it. When speaking of national laws they have no option but to follow them.

Finally all, users of public facilities although have no influence towards the realization of the project will greatly benefit from it. By means of the application of the NRD-2 their well being in case of the occurrence of a natural or man-made disaster will be ensured.

Part D: SCENARIOS

The development of scenarios is a key element for this research. Scenarios are descriptions of potential situation that may arise within a certain time frame and are used to evaluate the subject in question. For this research scenarios were developed taking into account potential natural and man-made disasters and the direct impact the NRD-2 would have in diminishing potential harms to public building users in the case of an emergency.

6 SCENARIOS

In order to evaluate the importance of the development of the NRD-2 it was necessary to first make a risk assessment by means of the evaluation of possible scenarios. Leading expert on scenario planning and CEO of Global Business Netowork, Eamonn Kelly, says that "Scenarios enable new ideas about the future to take root and spread across an organization – helping to overcome the inertia and denial that can so easily make the future a dangerous place." (Scearce, Fulton, 2004)

As part of the brainstorming process, the group of engineers in charge of developing the NRD-2 got together and thought out possible scenarios that could help guide and understand the important safety factor need to be addressed by the normative. Before revealing the scenarios considered, a brief explanation on what consists scenario planning will be given in the following paragraphs.

Scenarios are stories about how the future might unfold for an organization, an issue, the nation or even the world. Above all, it is important to understand that scenarios are not a prediction but rather a provocation and plausible stories about different ways the same situation can unfold and lead to different outcomes. Because scenarios are hypotheses, not predictions, they are created and used in sets of multiple stories, usually three or four that capture a range of future possibilities, good and bad, expected and surprising.[27]

Some steps need to be addressed in order to fully and comprehensively use the scenario planning techniques. It is of importance to understand that the main objective behind the development of the NRD-2 is for the safeguard and well being of the people within public buildings during every day use as well as during an emergency.

The first step in scenario planning is to establish a timeframe for the scenario thinking process. In the case of the application of the safety measures that will be specified by the NRD-2 it is a good guess to set the timeframe as for 1 year of use. The NRD-2 will touch topics of safety within public buildings during any type of emergency or even every day use. Meaning then that in one year several possible emergencies can occur that can affect that building. Events such as earthquakes, hurricanes, fires, shootings or as simple as an overuse of the facilities are plausible situations that can lead to fatalities. Chapter 4 of this thesis thoroughly displayed different natural hazards that the country encounters on a yearly basis. Therefore, setting the time frame for the scenarios as one year seemed correct.

As to lead the scenario thinking it was necessary to pose a focal question that is as objective as possible and has to be set within the chosen timeframe. In this case the focal question was set to be:

***Which are the safety elements (non structural) all public buildings should count with in order to safeguard the users from any harm a natural or man made emergency situation within the next year my cause on them*?**

[27] *What are scenarios?, Scearce, Fulton, GBN, 2004, San Francisco, CA, USA*

This focal question makes emphasis on the terms "safety elements" and "natural or man made emergency". All throughout this process it was very important to remember this terms in order not to side track from the main objective and even though this subject might sound very trivial it is one that needs to be taken very seriously since human lives are at stake.

To answer the focal question it was then necessary to come up and develop certain scenarios that would lead into finding out what safety elements need to be taken into account. Chapter 4 of this thesis lists many natural hazards Guatemala has encountered in the past as well as in the present year providing enough substantial data that Guatemala does see its fair share of disasters on a yearly basis. With this information it is then possible to create scenarios that included the potential natural hazards and evaluate their impact on public buildings and therefore the well being of the users.

For that reason the first major concern while developing the scenarios was that of the occurrence of an earthquake. This situation can bring with it many others in a snowball effect. Such effects would be seen as: loss of power, fires, gas leakages, crumbling materials, panic in conglomerated areas (such as auditoriums and classrooms), disorientation, etc.

So, as a second step, after realizing what hazardous situations could raise from an earthquake the following scenario was developed:

6.1 Scenario 1: Earthquake

Guatemala has not seen an earthquake of the same magnitude as the one from 1976. Meaning that a great part of the current populations has never been in a situation such as that one. A great number of new buildings have been constructed since that historical moment and with the lack of construction safety being enforced because of the non-existence of a national building code, many if not the majority of new constructions are uncertain of whether or not they are capable of sustaining a blow of such magnitude where it be to come in the near future.

Parenthesis: The question of structural safety is not topic of this conversation, since the development of this norm takes only into consideration the safety aspects within a standing structure that should be in place even before any signs of problems in order to inform the users of the actions they need to take in case of an emergency situation.

At the end of 2011 the unexpected happens, and a magnitude 8 earthquake shakes Guatemala at exactly 1400 hours. Meaning that most people are at their jobs and offices located in what are considered to be public buildings. Most buildings are able to sustain the blow and are still standing but people still need to get out.

6.1.1 Scenario 1.1: Worst Possible Outcome

In the worst possible outcome, following an event as the one described in section 4.1, a total collapse of a building structure would occur, meaning that everyone harbored inside of that facility would be killed. Nothing else can then be done or could have been done to prevent this that would be relevant to the subject of this investigation.

6.1.2 Scenario 1.2: Miscommunication and Panic

Another possible situation that can arise as part of the aftermath of such event would be that a standing structure, holding hundreds of people within its walls needs to be evacuated but, the safety information needed for the people to exit in a safe way is not there.

This lack of information in such a crucial situation would place the people in harms way. Not only by creating disorientation and panic but above all bringing upon them the feeling of loss of control. People would start to act in a manic behavior, trying to get out of the building any way they can; whether it is by harming others, harming one self that can lead to serous injuries or even death.

6.1.3 Scenario 1.3: Organized and Safe Evacuations

The NRD-2 main objective has to do with the realization of this scenario where a standing public building holding hundreds of people within its walls needs to be evacuated after a major earthquake and actually counts with the necessary safety elements to do so in a orderly and safe manner.

The best possible situation will be the one where a building is equipped with safety elements such as functioning emergency exits, clear and legible safety signs, emergency illumination, corridors and hallways clear of any debris, emergency ramps, emergency stairs, etc.

Having all of these elements in place is only the first part of the solution; the second part has to do with the understanding of these messages by the users of the facility. It doesn't make any difference whether or not there is a clear way to safety if people don't understand how to get there. Therefore, the locations and signaling of the safety elements have to be clear and strategically position so people will see and read them during non-emergency times and by that be able to remember them or remember to read them during an emergency.

6.2 Scenario 2: Fire

In case of the occurrence of fire the same principles for evacuation as for an earthquake should apply since the main objective is to safeguard the people from any harm and have them safely evacuate the premises. For that, it is not necessary to give another extensive explanation such as the one given for scenario 1. Nonetheless, it is important to emphasize that the safety measures that will be taken into consideration on the NRD-2 will be able to be applied in case of a fire but will not hold the specifics for fire protection. This information is thought to be explained when the fourth NRD is developed, consisting of "fire protection elements".

6.3 Scenario 3: Overcrowded Spaces

Lets say that Saturday night comes along and it is the grand opening of a new nightclub. Everyone who is anybody has to be there, and even though the space available within the club is made up to safely hold 500 people, the owners allow for 1,000 people to get in since more people equal more business for them. Safety measures say that a sign stating the maximum capacity of the club should be posted on the entrance, but since there is no law that regulates this, nobody takes it seriously.

Unexpectedly someone trying to be funny pulls out a firecracker and blows it inside the club making it seem as if a gun just went off. Everyone starts to panic and runs towards the exits. Being dark as in a typical nightclub, people intending to run towards an exit, start running towards each other pushing and shoveling who ever is in their way. People fall on the ground and get stepped on, others who do get to the exit try to go out at the same time getting stuck and preventing others from exiting.

The description just given is far too familiar and situations such as this one have indeed happen all over the world and have been part of a news report because of the fact that in most cases people end up dying. The NRD-2 intends for the overcrowding of spaces not to happen by means of having every facility state its maximum capacity and if violated attend to the consequences such as fines, or even its shutting down.

6.4 Landslide and Volcano Eruptions

Landslides are very common within the Guatemalan territory. Guatemala is known for its mountain ranges and valleys that give the country its charm. Nonetheless, this geography although beautiful at times posses grave dangers to the people with the occurrences of landslides. In 2005, tropical storm Stan hit Guatemala causing the oversaturation of the soils leading to serious landslides; the worst one being that of Panabaj where the entire village was taken by the mud that came down the mountain; it was estimated that 2,000 people lost their lives there. The national government has declared that area a massive graveyard where anyone declared missing is now considered as perished.

On May 27, 2010 the Pacaya volcano erupted, followed by several tremors. At approximately 20:00 hours there was a strong eruption ejecting debris and ash columns up to 1,500 meters. Ash rained down in many Guatemalan cities to the northwest of the volcano, including the capital. At the same time, the country was hit by Tropical Storm Agatha which worsened the emergency situation, causing lahars, landslides and widespread flooding across the county.

These events only demonstrate how important the safety of people within public buildings is. Many public schools are still located at foothills and near volcanoes. It is evident that the location of these buildings is not an acceptable one, but Guatemalan villagers have to do what they can with what they have. If the government is not able to provide them with a safer space where to build they will continue to use those unsafely located buildings. Therefore, it is important to evaluate the safety within these buildings to at least give the users the probability to evacuate in case of an emergency.

By allowing ourselves to think on the possible situations that could place the well being of public building users in harms way and evaluating other existing codes, it was possible to grasp the necessary elements that needed to be addressed by the NRD-2. The next section gives a thorough explanation of such criteria.

Part E: MINIMUM SAFETY MEASURES FOR PUBLIC BUILDINGS IN GUATEMALA

The Second Disaster Reduction Norm or NRD-2 for short takes into consideration all safety aspects for buildings of public use in Guatemala. A building of public use is defined by a structure that holds activities involving people visiting the structure in question. This includes office buildings, schools, markets, health and recreational centers.

In order to guarantee the safety of the users, all buildings of public use must follow several safety specifications. These specifications are described in the NRD-2 and are explained in this chapter. Two examples are then shown to demonstrate the application of the NRD-2 in order to determine the implementation of such safety measures in public buildings as well as an evacuation model is depicted in order to verify the importance of such norm and the safety of people. An evaluation format has been developed to evaluate existing buildings and determine the changes if any needed for them to comply with such norm.

7 ASSESSMENT CRITERIA FOR SAFETY MEASURES

In 1985 the European regulators concerning the methodology of regulations adopted the "new approach". It reflects the experience of years of development of regulatory documentation in Holland closely linked to the developments on the European level.
The guiding elements of the new approach were:[28]

- Formulate functional requirements and leave technical solutions as much as possible to the market; aiming at opening the market for technical innovation.
- Use only functional specifications if possible, which means setting quantifiable, measurable requirements; the result to be that in case of disputes it can be known what one is talking about.
- Do not regulate in the public domain what can be regulated in the private domain; aiming at creating more flexibility in regulating the relations between public and private parties.
- Do not make mandatory what can be solved voluntary; aiming at creating consensus and self regulation which requires less governmental surveillance.

The guiding elements described in the previous paragraph where also taken into consideration in the selection of criteria and development of the NRD-2. It is important to note that for the norm to be implemented as best as possible and for those implementing it to be held accountable it is first necessary to define the functional specifications or assessment criteria that can be easily quantifiable and measured in order to determine its level of implementation.

As mentioned before, Guatemala's construction industry has for a long time been using international codes with certain modifications in order to fit them to the country's needs. Therefore, it was not a question of finding out which aspects were needed in the new NRD-2 but how they should be applied.

A comparison of set criteria was made against the Dutch Regulations with Regards to Safety document provided by Mr. Groosman of the Expertisecentrum Regelgeving Bouw. Sustained by the "decree of August 2001, laying down regulations with regards to structures on ground safety, health, usability, energy-saving and environment (Building Decree)," and the 2009 International Building Code.

The NRD-2 is the result of the vision to continue with the development of a national building code for Guatemala. As mentioned before, AGIES together with CONRED have been working on the passing of several National Disaster Reduction Norms that will together form the Guatemalan National Building Code. The NRD-1 was subject of all structural and engineering aspects of a construction. The NRD-2 moves then to specify the Minimum Safety Measures for Public Buildings in Guatemala and is the main subject of study for this research. Several aspects of this norm will be analyzed and its application evaluated on this section; the complete norm can be found in Appendix A of this paper.

[28] *TNO Building and Construction Research, written by Dr. N.P.M. Scholten in 1997.The Netherlands*

This agreement aims to establish the minimum technical standards and safety criteria to be observed in buildings and facilities of public use and to protect the people in case of natural or man-made events that could jeopardize their safety. The Minimum Safety Measures are a set of standards and actions contained in this norm to be implemented in buildings and facilities of public use to achieve the described objective.

7.1 Responsible Authorities

To start a normative it is necessary to have a clear view of those responsible for its implementation or those accountable for the lack of implementation. Since the normative is being focused on all constructions and facilities of public use it was obvious that those responsible had to be the lead institutions of each sector or activity. For example when a school is in consideration, the lead institution and therefore responsible authority would be the ministry of education.[29]

Article 2 of the agreement states that in to fulfill the objective of this norm and to implement the Minimum Safety Standards and Emergency Planning, it establishes as responsible the lead institutions of each sector or activity, by means of what is stated in Article 4 of the Legislative Decree 109-96, and is shown in table 2.

SECTOR / ACTIVITY	LEAD INSTITUTION
Hospitals	Ministry of Health
Schools	Ministry of Education
Official Buildings	Secretary of official activity
Other buildings	Owner or person in charge

Table 2. Responsible Lead Institutions per Sector or Activity

In case of multi-organizational events, the responsibility will be shared between the institution in charge of the location where the event is taken place and the institution in charge of the development and realization of the event.

The actions and omissions that constitute any infraction or breach of this norm will be sanctioned in accordance with the established article 20 of the 109-96 decree, without any prejudice that if the action or omission constitutes a felony or fault, the conducive will be certified towards the competent court.

This agreement applies to all buildings and facilities of public use that currently function as such, as well as those that will be developed in the future. Are considered buildings of public use, regardless of the property holder to which access is allowed, with or without restriction of staff (employees, contractors and subcontractors, among others) and/or users (as clients, customers, beneficiaries, stakeholders, etc). Therefore, all buildings in Guatemala, except private homes are considered by this norm.

[29] *Article 2, NRD-2*

The following are considered buildings of public use:

a) Buildings that are located on public or private offices;
b) Buildings for the establishment of shops, including markets, supermarkets, wholesales, outlets, malls and the like.
c) Buildings devoted to making all kinds of events;
d) Schools, public and private, including primaries, high schools, collages, universities and their extensions, or training centers, and the like.
e) Health Centers, hospitals, clinics, nursing homes, whether public or private;
f) Recreational centers, amusement parks, including outdoor playgrounds, cinemas, theaters, churches, clubs and the like.
g) Other buildings

For purposes of this regulation, those subject as responsible are the owners of each property including buildings and facilities. If the property in question is being used legitimately by someone other than the owner, both of which are jointly responsible for compliance with these regulations.

7.2 Project Emergency Response Procedures

Who ever is responsible for the construction or installation of new public use buildings should develop a procedure for responding to emergencies, which should be called Project Emergency Response Procedure and should contain the same minimum safety standards approved by this agreement. Those responsible for the building or facility in question must submit to their knowledge and assessment the draft for Emergency Response Procedures, to the competent authority prior to the start of works.

The competent authority should evaluate the projects and if it considers them adjusted to this regulation, shall, within thirty days approve of them. Managers should implement the measures contained in the relevant plan, within the stipulated thirty days, having to prove in a document its implementation to the competent authority.

Developing buildings are considered those that at the time this agreements term has begum they have already began their formal construction activities and have not yet been finished. The responsible for these facilities should present the projects Emergency Response Procedure Plan to which Article 4 refers to within the agreed thirty calendar days after the beginning of this agreements term and in any event, before the end of the works in question. Not even the competent authority with regards to the normative can neither accept nor validate the public opening of set public buildings without them counting with the Emergency Response Procedure Plan dully authorized.

For bindings that already exists but fall under this agreement must also implement an Emergency Response Procedures Plan, dully approved by the competent authority. Those responsible must present an Emergency Response Procedures Plan before the competent authority within twelve months of this agreements passing, meeting the requirements of Article 5, and have twelve months to realize the required physical modifications as stipulated by the plan.

The competent authorities must meet in a chronological matter the procedures that it has authorized, leaving proof of it on an Emergency Response Procedure Registry and having to emit monthly reports of the authorized plans to the Disaster Management Agency.

Buildings / Facilities	Present Plan before Competent Authority	Implementation (once it's been authorized by competent authority)
New	Before initiating construction	30 days
Developing	30 days	Before finalizing construction
Existing	12 months	12 months

Note: Competent Authority approval: 30 calendar days

Table 3. Emergency Response Procedures Due Dates

7.3 Occupancy Loads

The occupancy load refers to the capacity of an area to harbor within its physical limits a set number of people. Each building structure is equipped to hold different amounts of people at one given time and extending this capacity might pose high risks to those inside. For that, each type of building or facility counts with its own occupancy load. Table 4 shows part of the Occupancy Load table used in order to calculate the number of emergency exits needed depending on the type of building. The complete version of this table as well as the specifics on how to calculate the occupancy load can be found within the complete text for the NRD-2 in Appendix A of this thesis.

Use	Minimum of two exits, without elevators, are required whn the number of occupants is at least:	Occupancy Load Factor (square meters)
Aviation Hangars (with no rapairs area)	10	45
Auction salons	30	0.65
Auditoriums, churches, chapels, dance floors, stadiums, bleachers	50	0.65
Meeting and conference rooms, diners, restaurants, bars, exhibition rooms, gyms, stages	50	1.39

Table 4. Occupancy Load Factors

7.4 Emergency Exits

An emergency exit is a continuous mean without obstruction that leads to a public road and includes all the necessary elements such as hallways, alleys, doors, gates, exterior balconies, ramps, escalators, stairs, smoke enclosures, horizontal and vertical exits, emergency exit patios and yards.

The emergency exit is one of the key safety factors all public buildings and facilities must have in order to satisfy the safety needs of its users. The normative will give an ample explanation of the number, size and location of these exits with regards to the type of facility in question.

As the occupancy load increases, the number of ways out of a building needs to be increased in order to handle the capacity and to give the people additional options to get out. The IBC outlines the number of exit paths out of a room or space and then the number of exits out of a building, just like the branch lines of a plumbing system. The occupant load in the space or building determines the number of exits. Each space is evaluated individually to determine the number of exits needed. All of the occupant loads for each individual area of a single building must be added together to determine the total number of exits required for that building.

All emergency exits, including aisles and hallways, ramps and stairs must be illuminated at all times. And for buildings with an occupancy load of 100 or more people, all emergency lights must have an alternate power source that automatically activates in case the main power source fails. The alternate source can be a battery bank or an emergency generator.

7.5 Signs

A key safety feature all public buildings and facilities must have are emergency signs. Signs specifying the needed information for all users to be safe when beings inside the facility. Such signs must include:

- Maximum number of people
- Maximum lift capacity
- Emergency Exit
- Escape route
- Safety zone
- Meeting area
- Dirty or contaminated area
- Pollutant free area
- “Push to open”
- “Pull to open”
- “Break in case of an emergency”
- “Do not use elevators in case of fire of power outage”
- “No running”
- “Only authorized personnel”
- “Do not block”
- et.

Since the location of an exit is not always obvious or known by the people within a building, the path to an exit must be identified by exit signs. Exit signs must be visible from any direction someone may travel along the exit path. They must clearly indicate the direction of the exit path if it is not immediately visible. Exit signs are required whenever a room, space or building is required to have two exits or exit access doors.

The NRD-2 states the specifics of this signs and a complete list can be found under Article 28 of Appendix A of this thesis. The following image shows the specifics an emergency sign should hold in order to comply with the NRD-2 regulation.

Figure 7. Example of Maximum Occupancy Sign

The safety color table specifies the type of color each sign should portray with regards to the message its conveying and Table 5 shows this color distinctions. Figure 7 then being a type of sign where the maximum number of people allowed in that area is specified, will portray a blue color since it is an informative sign. Also, the color of the letter must contrast with the color of the sign in order to make it easy to read and see from a distance. Table 6 shows the contrasting letter color for each color sign. Finally all types of sign specified and used under the NRD-2 can be found on Appendix 3 of the norm located under Appendix A of this thesis.

The colors used in signage and marking of emergency exits will be identified according to the international system RBG 8 bits per channel for a total of 24 bits using hexadecimal notation. The identification scheme consists of 6 hexadecimal digits. From left to right, the first two digits represent the red channel, the next two digits represent the green channel and the last two digits represent the blue channel. The hexadecimal digits to be used are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

SAFETY COLOR	SIGNIFICANCE	INDICATIONS AND PRECITIONS
RED Cod. FFOOO	Stop	Stop some place
	Forbidden	Sign to forbid specific actions
	Material, equipment and systems to fight fire.	Location of fire fighting materials and equipment.
YELLOW Cod. FFFF33	Danger warning	Attention, precaution, verification and identification of dangerous situations.
	Area delimitation	Restricted área limits or of specific use.
	Danger warning due to ionized radiation	Sign to specify the presence of radioactive material.
GREEN Cod. 009900	Safe condition	Identification and signaling to indicate emergency exits, evacuation routs, safe zones, meeting points, emergency showers, eye washers, etc.
BLUE Cod. 000099	Obligation, information	Signaling for the realization of specific tasks. Provide information for all people.

Table 5. Safety Colors

Color	Contrast
BLUE Cod. 000099	WHITE Cod. ffffff
GREEN Cod. 009900	WHITE Cod. ffffff
YELLOW Cod. FFFF33	BLACK Cod. 000000
RED Cod. FFOOO	WHITE Cod. ffffff

Figure 6. Contrasting Colors

8 APPLICATION OF NRD-2

The purpose of the NRD-2 is to be used and applied in all new and existing public buildings in order for them to count with the minimum accepted safety measures stated by the norm. In order to show the way the norm shall be used, the following examples are used. These are random examples taken out of existing books found within the offices of AGIES they are not real cases.

The first example is with regards to an auditorium and the second with regards to a shopping center. In both examples, the minimum accepted number of emergency exits, their dimensions and locations are calculated and shown by means of the buildings occupancy load. Examples on specific signaling and its location will not be shown on this section since they are specifically explained by the norm and don't require any mathematical calculations to take place.

8.1 Example 1: Auditorium

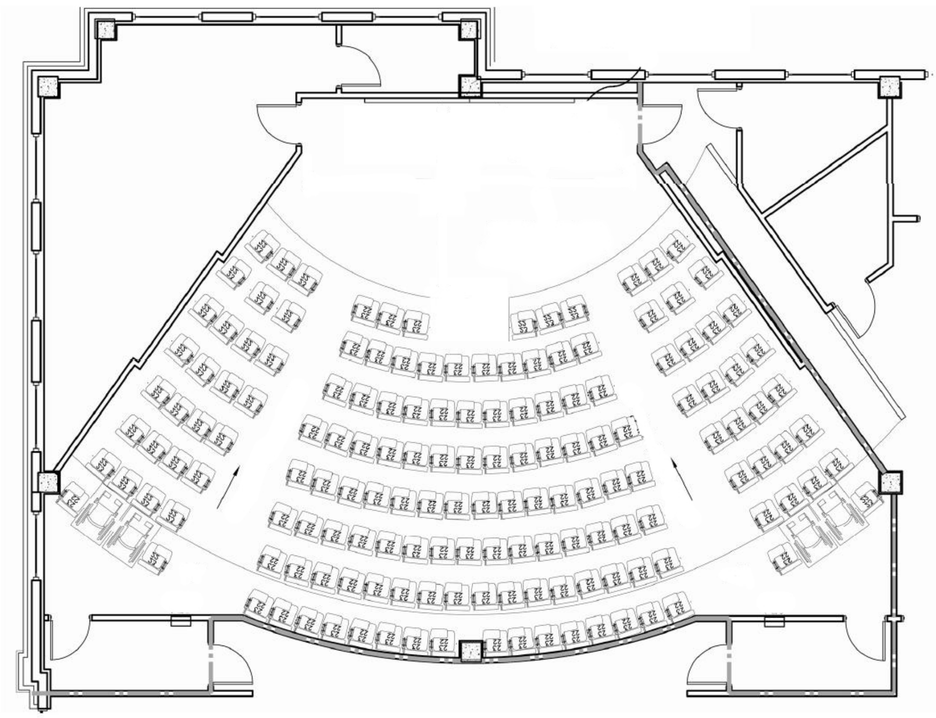

Figure 8. Auditorium Blueprint

The following auditorium has a capacity to hold and seat 161 people. It has two access ramps with a slope of 1:12 (8.33%) and it has two exits of 90 centimeters each.

Step 1. Determine the Occupancy Load

Article 10b. For areas with fixed seats, the number of fixed seats will determine the occupancy load. The required corridors length between seats cannot be used for any other purpose. For areas that hold fixed benches, the occupancy load must be less than one person for every 45 centimeters of bench. When there are cabins in food areas, the occupancy load must be one person for every 60 centimeters of cabin.

Occupancy Load = Number of Seats = 161 people

Step 2. Determine the minimum number of Emergency Exits

Every building or its utilized part must count with at least one emergency exit. No less than two when it is required by table 1 and additional exits when:

a) Each level or its part with an occupancy load of 501 – 1,000 people must have no less than three emergency exits.

Table 1 states that for auditoriums a minimum of two emergency exits are required when the number of occupants is at least 50.

Occupancy Load = 161 people > 50 but less than 501
Minimum number of Emergency Exits = 2 → OK

Step 3. Determining the width of the Emergency Exits

Article 14. The total emergency exit width in centimeters will not be less than the occupancy load multiplied by 0.76 for stairs and 0.50 for other types of emergency exits, nor will it be less than 90 centimeters. The total width for emergency exits must be equally divided between all emergency exits and the maximum width of required emergency exits of any level must be kept throughout the entire building.

Exit width = 161 x 0.50 = 80.5 cm → 90 cm minimum
Exit width according to plans = 2 x 90 = 180 cm > 90cm
0k

Step 4. Location of the Emergency Exits

In the case where the requirement is met by two emergency exits, these must be located with a separation measured in a straight line between them of no less than half the distance of the largest diagonal of the building or area to be evacuated.

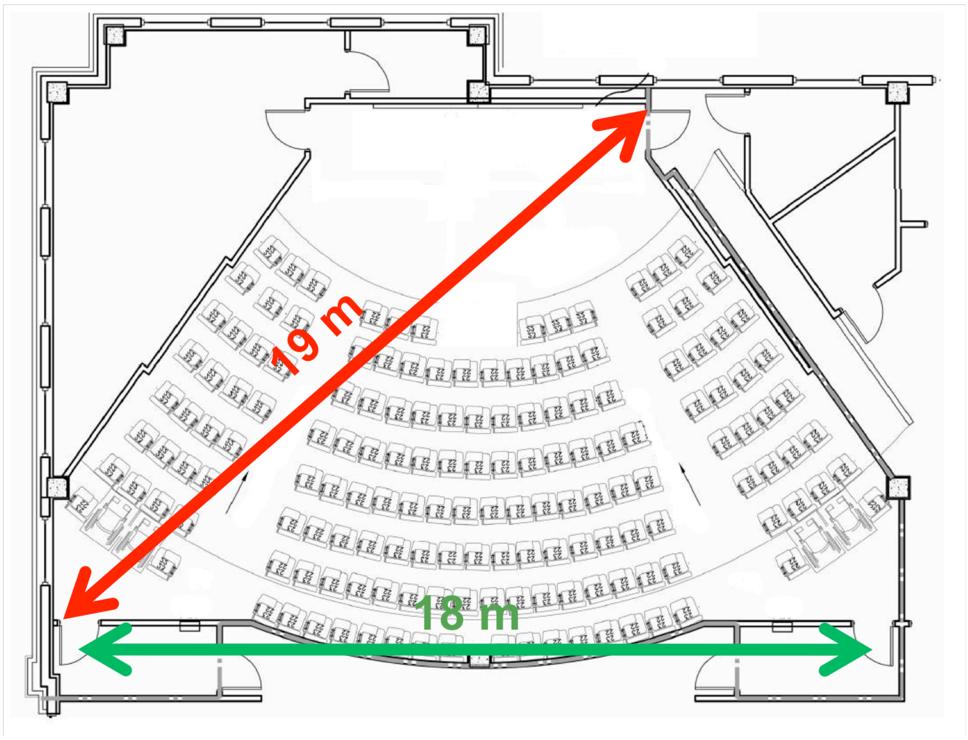

Figure 9. Emergency Exit Location

Minimum distance between Exits = 19/2 = 9.5 m
Distance according to the plans = 18 m > 9.4 m → OK

Step 5. Ramp Width

The minimum width for ramps used in escape routs shall be as indicated by article 14 but no less than 90 centimeters for occupancy loads smaller than 50 and 110 centimeters for occupancy loads of 50 or more.

The maximum slope for emergency ramps must be of 8.33 percent when used by people in wheelchairs or 12.5 percent when not used by people in wheelchairs.

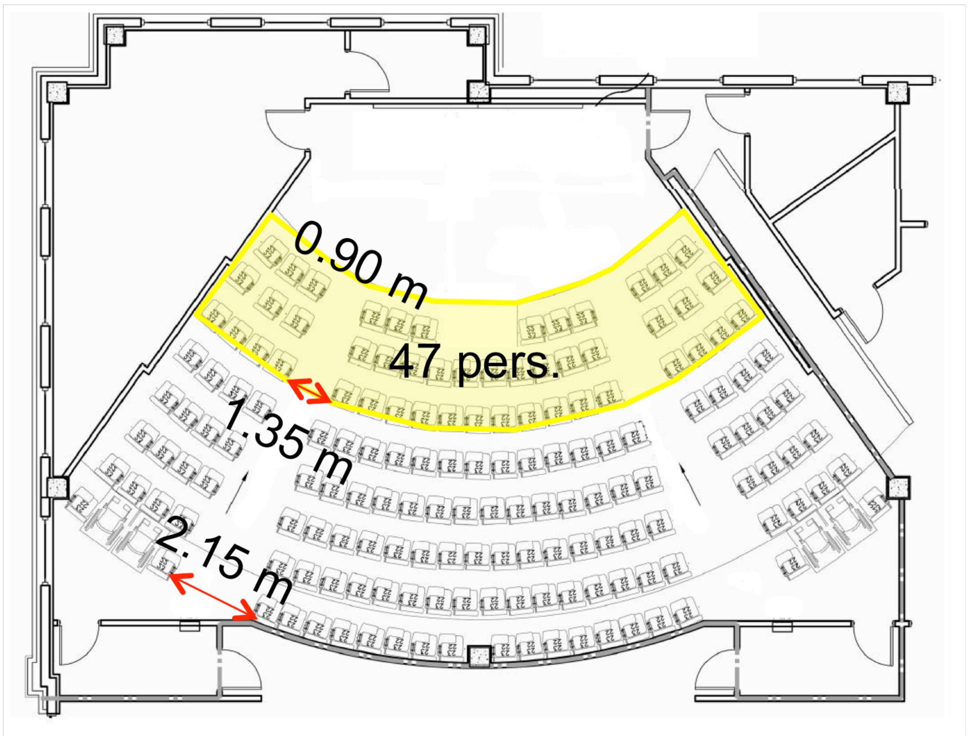

Figure 10. Ramp Width

Distance according to plans = 135 cm > 90 (load = 47/2 = 24)
Distance according to plans = 215 cm > 110 cm (load = 161/2 = 81)
→ OK

Step 6. Distance Between Fixed Seats

The minimum free space between seat rows must be:

- 30 centimeters for rows of 14 or less seats.
- 30 centimeters plus 0.76 centimeters for each additional seat after 14 to a maximum of 56 centimeters.

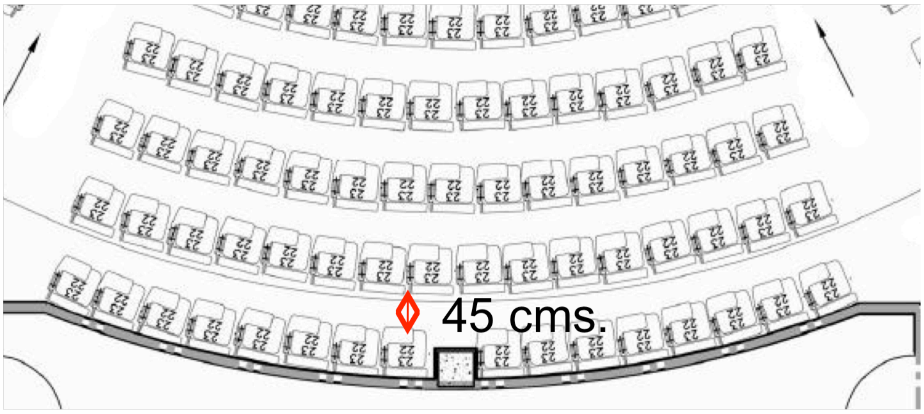

Figure 11. Distance Between Seats

Number of fixed seats in row = 16
Minimum required distance = 30 + 0.76x2 = 31.5 cm
Distance according to plans = 45 cm > 31.5 cm
OK

8.2 Example 2: Shopping Mall

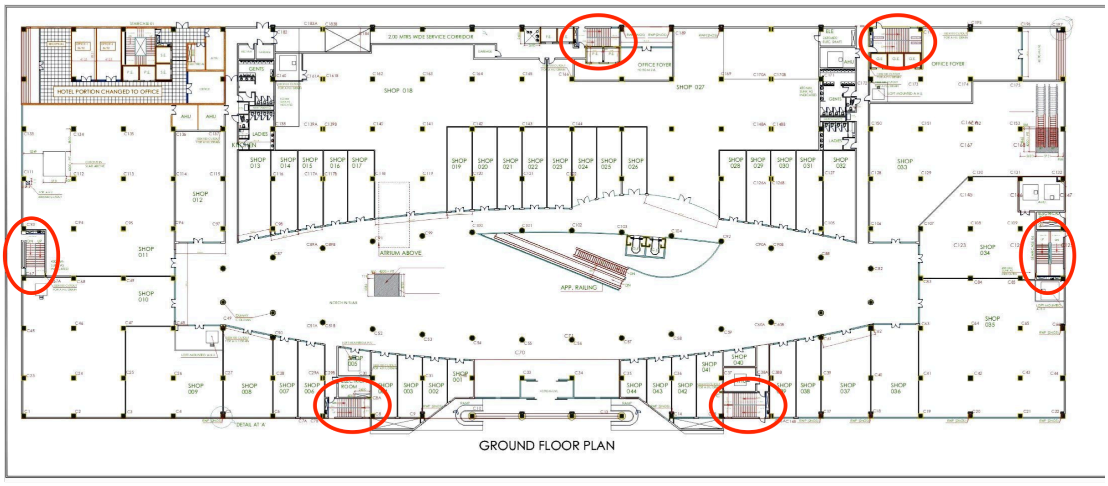

Figure 12. Shopping Mall

The shopping center portrayed in this example has two levels measuring 97m x 36m each. It has six emergency exits by means of corridors and stairways measuring 1.10m and 1.60 m respectively.

Step 1: Determining the Occupancy Load

Article 10a: For areas that do not hold fixed seats, the occupancy load can't be less that the floor area (square meters) divided by the factor indicated in table 1. When the structures use/type is not specified in table 1, it must be calculated using the type that seems most likely to its real use. For buildings or part of buildings with multiple uses, the occupancy load must be calculated with the one that results from the larger number of people.

Table 1: Shopping Center, Load Factor = 2.8
Floor area per level = 97m x 36m = 3,492m^2
Occupancy Load per level = 3,492/2.8 = 1,247 people

Step 2: Determining the minimum number of Emergency Exits

Article 13: Every building or its utilized part must count with at least one emergency exit. No less than two when it is required by table 1 and additional exits when:

b) Each lever or its part with an occupancy load larger than 1,000 people must have at least four emergency exits.
c) The number of emergency exits required by any level must be determined by means of its own occupancy load plus the following percentages of the occupancy loads of other levels which connect to the level in question:
    a. Fifty percent of the next upper levels occupancy load and 50 (fifty) percent of the next lower levels occupancy load.

b. Twenty five percent of the occupancy load of the upper level to the next upper level of the level in consideration.

Level 2: Occupancy Load = 1,247 → minimum of 4 exits
Level 1: 1,247 + 1,247x0.5 = 1,871 → minimum of 4 4xits
Number of Emergency Exits seen on plans = 6 → OK

Step 3: Determining the total width of the Emergency Exits

Article 14: The total emergency exit width in centimeters, will not be less than the occupancy load multiplied by 0.76 for stairs and 0.50 for other types of emergency exits, nor will it be less than 90 centimeters. The total width for emergency exits must be equally divided between all emergency exits and the maximum width of required emergency exits of any level must be kept throughout the entire building.

Total width of corridors = 1,247 x 0.50 = 624cm
Width of each corridor (6 corridors) = 624/6 = 104 cm = 1.04 m
Total width of stairs = 1,247x0.76 = 948 cm
Individual width of stairs (6 stairways) = 948/6 = 158 cm = 1.58 m

Step 4: Emergency Exit Location

Article 15: When three or more exits are required, at least two of them bust be located with a separation measured by a straight line between them of no less than half the distance of the largest diagonal of the building or area to be evacuated. The additional exit(s) must have an adequate separation between them, so than if one of them is blocked the others remain available for evacuation.

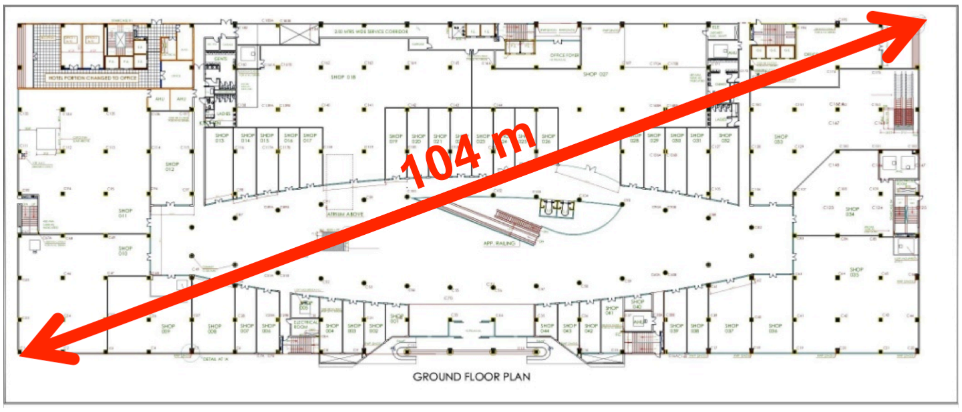

Figure 13. Emergency Exit Location

Minimum distance between Exits = 104/2 = 52 m
Distance in plans = 97 m > 52 m → OK

9 EVACUATION ANALYSIS

Evacuating a building successfully in moments of an emergency is very important in order to ensure the well being of its users. An evacuation can go from a simple drill to an actual emergency situation such as a fire within the surrounding area or building itself. In order to allow the buildings users a successful evacuation the building must be equipped with certain safety measurements that will aid in the process. All of these measurements have been thoroughly explained by the NRD-2 and its application demonstrated by the examples on the previous section. Nonetheless many variables come into play when an evacuation takes place and to ensure its success. Variables that need to be examined are not only the existence of emergency exits but whether or not these exits are fully accessible and not blocked.

To provide the maximum level of safety in the events of a fire within buildings of public use, buildings must be properly constructed and be provided with fire protection systems that detect and suppress fires and alert occupants. Codes and standards require life safety measures in the form of construction and egress components. The human interface with the fire protection and egress components is a critical factor in the provision of an acceptable level of life safety in the event of a fire. Building occupants must know what the evacuation alarm sounds like, where the exits are, and the proper response during an emergency. Emergency plans and workplace fire drills address the human element in the protection of lives in the event of fire. [30]

A critical success factor during an evacuation is the speed on which people are able to exit the area that poses a danger. This speed will vary depending on the situation and also on specific characteristics of each person such as age, physical condition and stress levels. Also, evaluations that take place in the construction of new buildings in order to verify whether or not they comply with what the NRD-2 stipulates must be evaluated once more after completing the construction. There have been examples in history such as the Kansas City Hyatt Regency Hotel walkway collapse where this verification did not take place and lead to a catastrophic accident.

The existence of fire codes and building codes make it easy for architects and engineers to apply them since they only have to consult them and find the factors that apply for that specific structure and follow the regulations that have already been set. In applying these fire safety regulations to building design, the engineer does not have to consider what is actually safe. The safety is already implicitly embodied in the stated values. Nonetheless, this brings some deficiencies with regards to regulations since they are rather inflexible and more often than not refer to specific and common building types.[31]

If the building in question does not fit into any standard type of building the most suitable design regulations must be followed from the standard code which may lead for the engineer to incorporate too many or inappropriate safety measures which can translate into unnecessary costs. There's a fine line between incorporating the necessary safety regulations and having too many just to be safe but increasing the costs of construction where not needed. There are no straightforward answers for finding the balance between this tradeoffs and it is because of that, that it has become very

[30] *Demers and Jones, 2001, Emergency Evacuation Drills, pp. 9*
[31] *Frantzich, 1998, Uncertainty and Fire Risk Analysis in Fire Engineering, pp 1*

important to implement Fire Risk Analysis in order to better define the appropriate levels of safety measures for a specific construction.

9.1 FIRE RISK ASSESSMENT

Fire safety is only one of many safety issues management must address to minimize the risk of injury or death to staff or the public. Unlike most of the other safety concerns, fire has the potential to injure or kill large numbers of people very quickly. Therefore, the fire risk assessment even though it is concerned only with fire safety can also be used to evaluate the impact upon other safety issues and vice versa.

Good management of fire safety is essential to ensure that fires are unlikely to occur; that if they do occur they are likely to be controlled or contained quickly, effectively and safely; or that, if a fire does occur and grow, everyone in the premises is able to escape to a place of total safety easily and quickly.

The risk assessment that management must carry out will help ensure that the fire safety procedures, fire prevention measures and fire precautions (plans, systems and equipment) are all in place and working properly, and the risk assessment should identify any issues that need attention.

A fire risk assessment is therefore an organized and methodical look at the premises, the activities carried on there and the likelihood that a fire could start and cause harm to those in and around the premises. The aims of the fire assessment are:

- To identify the fire hazards.

- To reduce the risk of those hazards causing harm to as low as reasonably practicable.

- To decide what physical fire precautions and management arrangements are necessary to ensure the safety of people in the premises if a fire does start.

Within a fire risk assessment it is important to differentiate between to terms that are widely used, them being: 'hazard' and 'risk'.

- **Hazard**: anything that has the potential to cause harm
- **Risk**: the probability of that harm occurring.

A fire risk assessment will then help determine the probability of a fire starting and the dangers from fire that the premises present for the people who use then and any person in the immediate vicinity.

There are five steps that need to be addressed in a fire risk assessment, all of which will the thoroughly analyzed in the subsequent sections. Appendix D shows a complete Evaluation Form to be used in a Fire Risk Assessment. The steps are as followed:

Step 1: Identify fire hazards (sources of ignition, sources of fuel and sources of oxygen)

For a fire to star, three things are needed; a source of ignition, fuel and oxygen. If any one of these is missing a fire cannot start. Taking measures to avoid the three coming together will therefore reduce the probability of a fire occurring.

Examples of sources of ignition for an auditorium (example used in this analysis) might be:

- Smokers material such as cigarettes, matches and lighters;
- Electrical, gas or oil-fired heaters (fixed or portable), room heaters;
- Hot processes such as welding by contractors;
- Faulty or misused electrical equipment;
- Light fittings and lighting equipment such as halogen lamps or display lighting;
- Hot surfaces and obstruction of equipment ventilation; and
- Arson

Anything that burns is fuel for a fire, it is necessary to look for the things that will burn reasonably easily and are in enough quantity to provide fuel for a fire or cause it to spread to another fuel source. Some of the most common 'fuels' found in small and medium places of assembly are:

- Flammable liquid-based products such as paints, varnishes, thinners and adhesives;
- Displays and stands;
- Costumes, drapes and hanging, scenery and banners;
- Decorations;
- Plastic and rubber, such as video tapes, polyurethane foam-filled furniture and polystyrene-based display materials and rubber or foam mats; and
- Upholstered seating and cushions, textiles and soft furniture and clothing displays.
- Materials used to line walls and ceilings should also be taken into consideration.

The main source of oxygen for a fire is in the air around. In an enclosed building this is provided by the ventilation system in use.

Step 2: Identify people at risk (People in and around the premises and people especially at risk)

All the people who use the premises must be considered, but special attention should be addressed to people who may be especially at risk such as:

- Organizers hiring the venue;
- Employees who work alone and or in isolated areas such as cleaners and security staff;
- Unaccompanied children;
- People who are unfamiliar with the premises such as visitors and customers; and
- People with disabilities (including mobility impairment or hearing or vision impairment)

Step 3: Evaluate, remove, reduce an protect from risk

- Evaluate the risk of a fire occurring;
- Evaluate the risk to people from fire;
- Remove fire hazards,;
- Remove or reduce the risks to people (detection and warning, fire-fighting, escape routs, lighting, signs and notices).

Step 4: Record, plan, inform, instruct and train

- Record significant finding and action taken;
- Prepare an emergency plan;
- Inform and instruct relevant people;
- Cooperate and coordinate with others; and
- Provide training.

Step 5: Review

Keep assessment under review and revise where necessary, if there is any reason to suspect that the fire risk assessment is no longer valid or there has been significant changes in the premises that has affecter the fire precautions, it is needed to review the assessment and if necessary revise it. Reasons for review could be:

- Changes to work activities, their organization or the introduction of new equipment;
- Alterations to the internal layout of the premises;
- Substantial changes to furniture and fixings;
- The failure of fire precautions such as fire-detection systems and alarm systems, life safety sprinklers or ventilation systems;
- A significant increase in the number of people present; and
- The presence of people with some form of disability.

9.2 FLOW-BASED EVACUATION MODEL

The model used to simulate the evacuation described in this section shows the tendency of a Flow-Based Model.[32] Such type of modeling employs a flow-based approach that models the density of nodes in continuous flows. Computer software's such as PATHFINDER enables the user to construct a simulated physical environment as a network of nodes. The nodes represent physical structures, such as rooms, stairs, lobbies and hallways that are all connected and comprise a single structure from which an evacuation is executed. The user defines the contents of all the nodes as networks, a step that involves the determination of how many people the particular node may contain; certain nodes are designed as destination nodes (exits), thus identifying all of the possible terminal points of occupant egress. For each node the usable area must be calculated and allowance is made for the presence of barriers, equipment, and other items as well as the space, which people lace between themselves and a wall. This latter feature entails the inward projection of each node wall.

Besides nodes, the model also requires the specification of arcs; or passageways between buildings components. The user must supply a 'traversal time' or the amount of time that it takes to cross the passageway as well as the 'arc flow capacity', which delimits the amount of human occupants that can travel the passageway per time period.

In terms of human occupants the node capacities are directly linked to the parameters that define the average pedestrian area occupancy, the average inter-person spacing and

[32] Santos, Aguirre, 2004, Flow-Based Modeling, Newark 2004

a brief qualitative description of conditions, as evacuees would experience them. Different parameters will describe situations such as "standing and free circulation" or other parameters can describe more extreme evacuation conditions in which persons are in direct physical contact with others around them, no movement is possible within the area and the potential for 'panic' exists.

The model then takes the complete network model and determines an optimal plan to evacuate the building in a 'minimum' amount of time. This is achieved using an advanced capacitated network flow transshipment algorithm, a specialized algorithm used in solving linear programming problems with network structures.

The egress evacuation is determined almost entirely on the basis of physical constraints such as the usable area, flow rates and the particular configuration of nodes. It is designed to produce results that take account of a fixed set of environmental features, assumed travel speeds and an arrangement of varying levels of service. Unlike other models, most social interaction elements are rendered irrelevant because evacuation times depend primarily upon node capacity and travel times. The consequence is that several sociological assumptions can be made but not articulated or translated into attributes or algorithms relating to the motion of a person.

The only control the user may exercise over a person is in setting the preliminary contents of rooms as well as setting the travel speed. Once again, this relies upon viewing the movement of evacuees as continuous flow, not as an aggregate of persons varying in physical abilities and individual dispositions.

9.3 HUMAN BEHAVIOR DURING EMERGENCIES

Smoke inhalation is the primary cause of death in victims of indoor fires. The smoke kills by a combination of thermal damage, poisoning and pulmonary irritation caused by carbon monoxide, hydrogen cyanide and other combustion products.

Human behavior has been recognized as a factor in the loss of life in fires for many years. Studies of human behavior during emergencies have assisted code developers and public educators to identify factors that affect occupant survival during a fire emergency. Human behavior studies indicate that the reaction of people to an emergency condition is related to a number of factors, including a person's assumed role, experience, education and personality as well as the emergency's perceived threat and the actions of other sharing the experience.[33]

- *Assumed Role:* The role an individual plays has an impact on his or her reaction in the event of an emergency. Individuals in leadership roles will regularly take charge. Employees may follow the lead of their supervisor or a long-term employee. Visitors in a facility will typically be more passive and look for guidance from other occupants or staff.

- *Experience:* Previous experience in emergency situations may cause one to react faster than someone who has never had to evacuate a building under fire conditions.

[33] *Human Behavior During Emergencies, 2001, National Fire Protection Association*

- *Education:* Individuals who have participated in drills and received training in emergency response react faster and with better decision making than those without training.

- *Personality:* The personality of an individual has an impact on how he or she will react in an emergency. Some individuals might attempt to fight the fire; others will attempt to escape immediately. Studies have shown that men are much more likely to attempt to fight the fire and women are more likely to leave th building as their first action.

- *Perceived Threat:* Before individuals begin to evacuate, they almost always seek to validate that there is, in fact, a problem unless there are obvious clues, such as smoke or visible flames, many people may not take immediate action in response to a fire alarm.

- *Actions of Others Sharing the Experience:* Individuals tend to function similarly to those they are with during the emergency. For example, if an individual panics, those around him or her are likely to do the same.

9.4 THE FIRE DRILL

The goal of fire drills is to familiarize employees as well as the public with emergency procedures and the location of means of egress components provided within the facility. The fire drill is a tool that is used to ensure that occupants react properly in the event of and actual emergency within a facility.

The following is a simulation where the evacuation of an auditorium takes place without the existence of a fire. This simulation can be taken as the control environment in order to later compare the reactions in the presence of a fire. The simulation was done by means of using the computer software Pathfinder 2011® of Thunderhead Engineering, it is an agent based egress and human movement simulator. It provides a graphic user interface for simulation design and execution for result analysis in the form of a Flow-Base Model. Figure 16 shows the image of the auditorium used for the simulation. As it can be seen it has a seating capability of around 110 with one primary double door exit and two single door emergency exits.

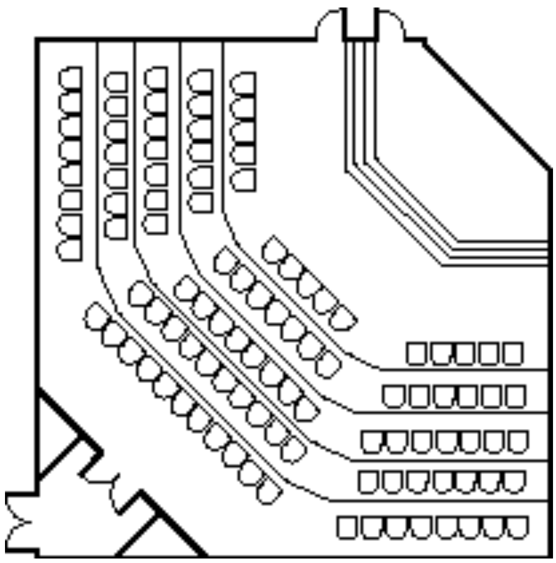

Figure 16. Auditorium used in Pathfinder®

As mentioned before, the area to simulate was that of an auditorium with a capacity of seating 110 people, nonetheless within the model the standard parameter was chosen where the program determines the average of occupants by means of the existing area. In the case of this example the computer set the amount of people to be 81.

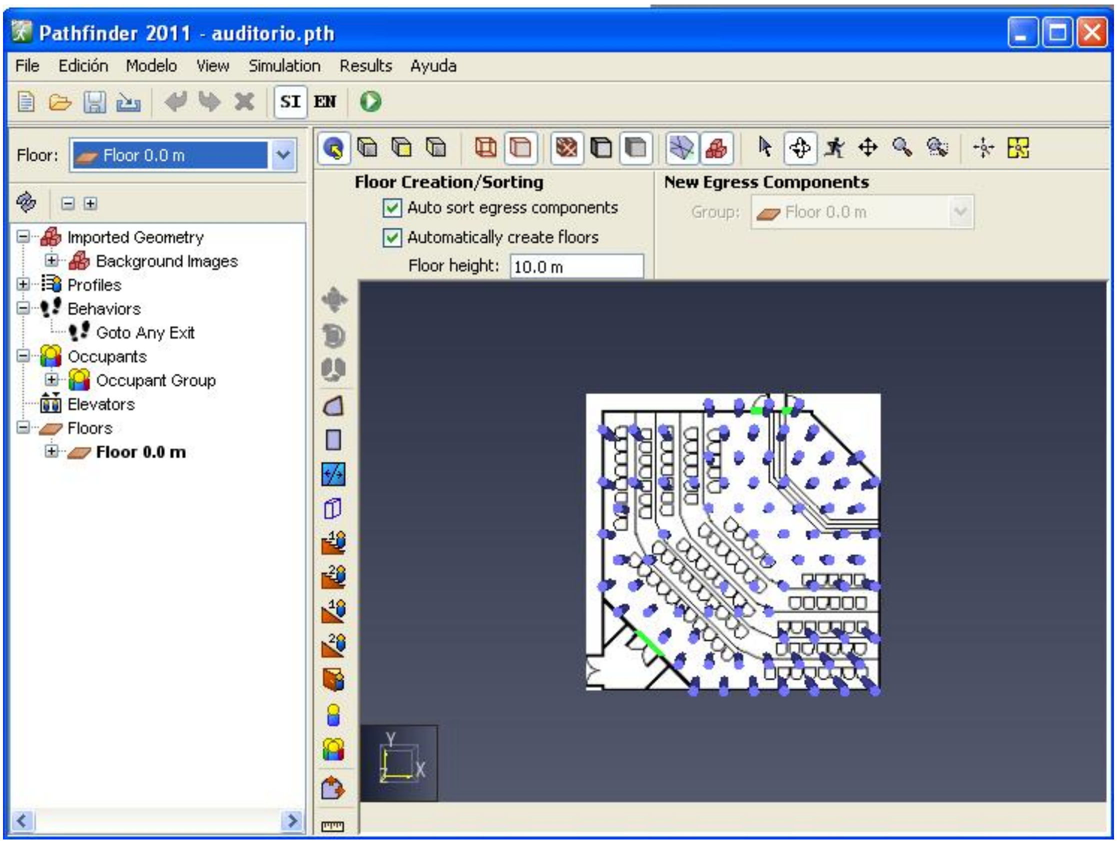

Figure 17. Auditorium filled with 81 people

The above figure shows the top view of the auditorium when it is holding the 81 people. Note that the people are filling the room in a random form, nonetheless barriers have been determine that will limit the spaces where the people can actually move in order to reach the exits. Such barriers include the seating area and walls, therefore only allowing the occupants to move through the corridors and stage area giving the simulation the most realistic scenario.

In the following images it is possible to see the simulation and the evacuation format that took place. All 81 people were evacuated in 18.8 seconds through the main and emergency exits. The computer software illustrates the evacuation in form of a video but the sequence of image that goes through the complete evacuation can be found in Appendix D.

The simulation results are then represented by several charts including the representation of the number of occupants, which have exit at a certain time until the room is completely empty after 18.8 seconds. Also it is possible to see the flow of people that each door had. Figures 19 and 20 show part of these results, the complete set of graphs and charts can be found in Appendix D.

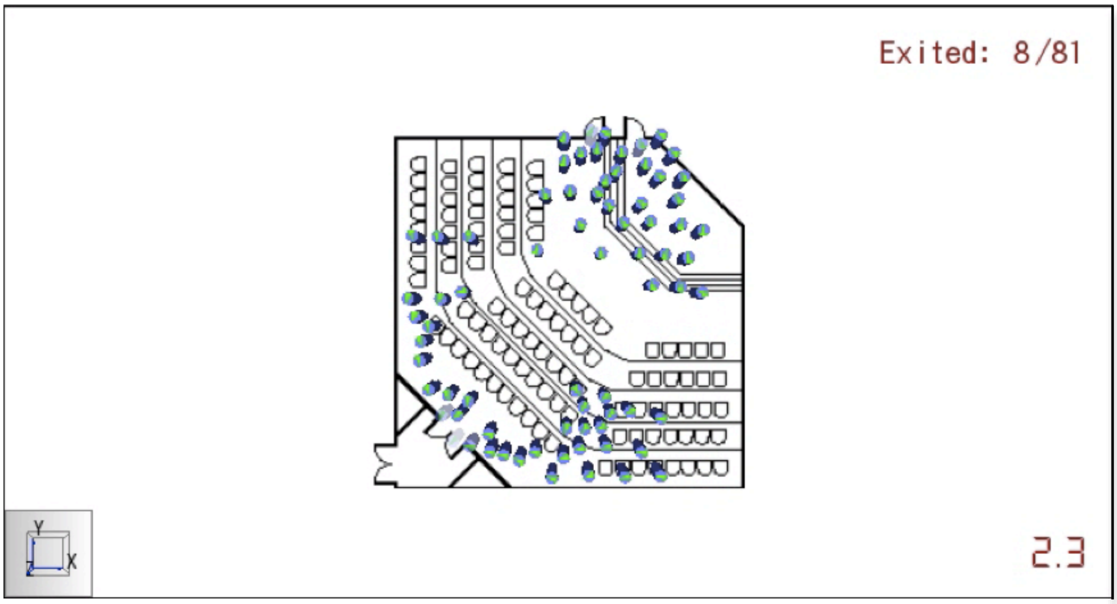

Figure 18. Evacuation Simulation

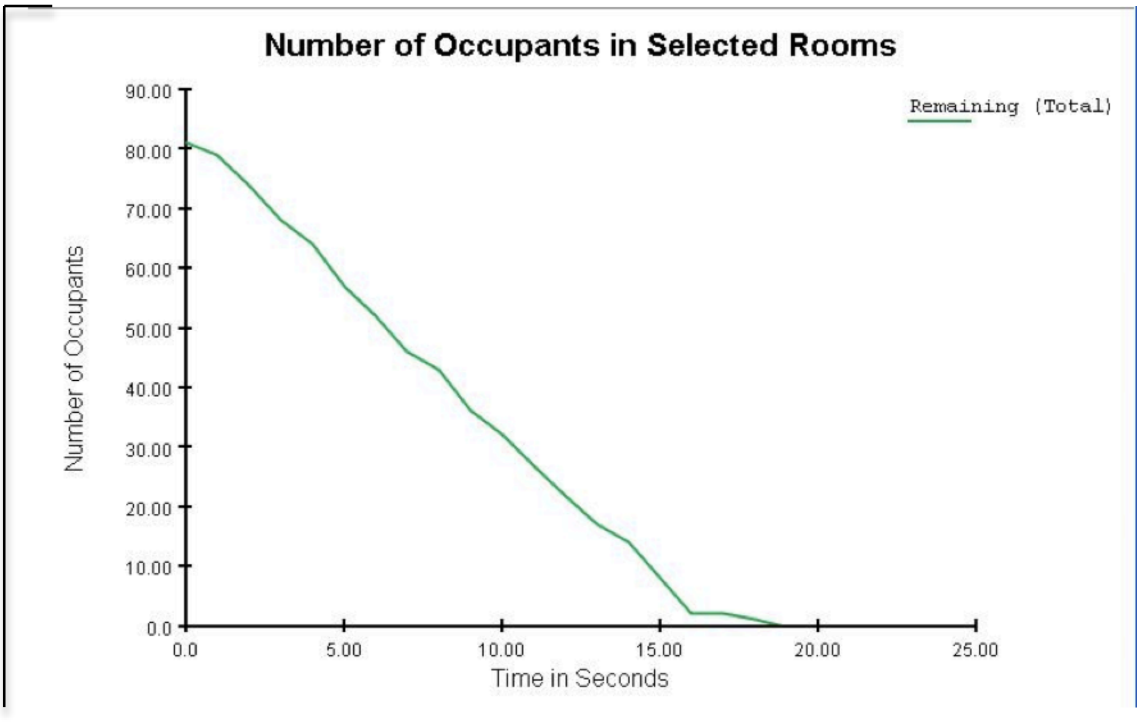

Figure 19. Exiting frame of Occupants

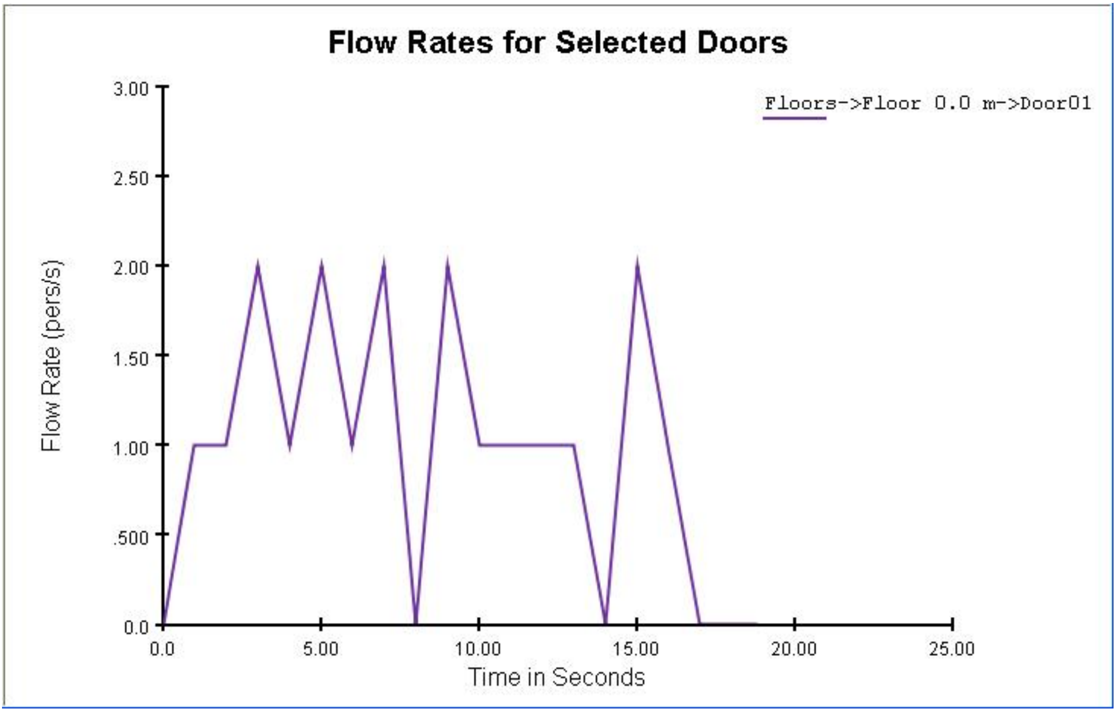

Figure 20. Flow Rate of Selected Door

9.5 EVACUATION ANALYSIS DUE TO FIRE

With Pathfinder® the control evacuation or emergency drill could be simulated. In order to replicate the reaction times and effects on an evacuation of the same space with the existence of fire a simple Excel spreadsheet was created. This spread sheet allows for many different variables to be altered in order to better illustrate the effects of a fire on an evacuation. Excel should be able to replicate the simulation that took place using the computer program. Once this replica took place it was demonstrated that the excel spread sheet would indeed represent correct and comparable results.

Figure 23 shows the comparable excel evacuation model to that of Pathfinder. The auditoriums conditions were replicated in the way that there was one main door measuring 1.8m and two emergency doors of 0.9m each. Also it was determined that for one person to pass through a door he or she needs a minimum of 0.9 meters (this variable can be change in order to evaluate the flow of people in the existence of a blockage). The critical survival time was set to 30 seconds only to verify how long it would take for the 81 people to exit the room. In case of fire this survival time can be changed and varied at will. A human being can survive within a dense smoke environment a maximum of 2[34] minutes. Depending on the severity of the event, this time will drastically decrease.

The simulation results can then be displayed for different times (in this case 30s). It is possible to see in figure 21 that at 18 seconds of the simulation 72 people have exited and at 21 seconds 84 people have exited, which demonstrates that around 18.8 seconds

[34] *Based on information gathered from the NFPA 101B handbook.*

more or less of 81 people will have exit the area making this and the Pathfinder computer model comparable.

9.5.1 Evacuation Analysis Factors

As mentioned before the Excel Evacuation Analysis (figure 21) takes several factors into consideration and they will be explained in more depth in this section in order to clarify their implications on the analysis and the reasoning behind them.

Number of People within the Space*:* In this cell the evaluator needs to input the number of occupants that were in the space at the time of the accident. This information help and aid researchers when making Risks Analysis of the area in question with regards to potential accidents that may occur and their implication on the loss of human life.

Number of main exits*:* A main exit is considered to be as one of the main means of egress from the premises, usually they will consist of double doors.

Width of main exit door: It is important to include this number because during the events of a disaster a compromised door space will influence the rate of exit flow of occupants.

The same information is asked with regards to the existence of Emergency Exit doors. Again the number of them as well as their dimensions is needed for the analysis to calculate the potential loss of life during an event.

Critical Survival Time: This variable can be manipulated depending on the type of fire (electrical, chemical, environmental, etc) and its implications on the situation. It is very hard to give concrete data on the critical survival time of a given situation since so many factors come into play. As mentioned before a human is only able to survive about 2 minutes in a dense smoke environment. Heat, fire spread velocity and flame distribution are other factors that can affect the outcome of a situation.

According to NFPA standards, once occupants have reached a 'fire rated passage or areas of refuge' (an area structurally design to isolate occupants from fire environments in order to give them the necessary time to be rescued) they have 20 minutes to be evacuated before the fire rated passage gives way and is unable to contain the fire within its outside borders.

Disabled Occupants: The existence of disabled or partially disabled occupants must already be taken into consideration in the creation of any emergency preparedness plan as stated by the safety codes. The time it will take this type of occupants to exits is already included in the needed evacuation time and it is why this type of seating's are strategically located around the area and specifically located near any means of egress.

Evacuating large crowds of people under any circumstance is a challenge; evacuating those large facilities during an emergency or disaster is a much more complex task because of the added elements of chaos, panic and the high density of the population. Determining the most effective evacuation plan for a large public facility requires in-depth analysis of multiple factors. Determining the best routes, foreseeing potential problems, addressing the panic factor, and orchestrating the evacuation are all critical aspects that should be evaluated in a well-developed disaster management plan.[35]

Panic Factor: For this analysis in particular the panic factor is taken as a so-called hydraulic model where people are assumed to flow out of a facility much like water flowing out of holes in a water filled tube. Modeling this takes into consideration typical rule-based average speed limits for the occupants and calculates the flow of people as they pass through openings. The computer evacuation simulation done by Pathfinder set the flow of egress to be 4 people/second for the main doors and 2 people/second for an emergency exit door. The excel spreadsheet used to show the evacuation simulation in case of an emergency uses the panic factor in order to reduce the flow of people able to pass through a door at a given time, translating into an increase in the evacuation time period which is then compared with the critical survival time giving as a result the amount of casualties that would rise given those specific conditions.

These flow-base modeling is a simple way to evaluate the egress of occupants during an evacuation. Nonetheless, these simplistic models are not generally capable of simulating human behavior or the interaction of people with their changing environment, and are not capable of assessing the effects of various, perhaps even multiple events that may occur during and evacuation. To take this factors into account larger computer simulators need to be used which for purposes of this analysis are not necessary but yet are important to be mention and how their use can better represent evacuation behaviors.

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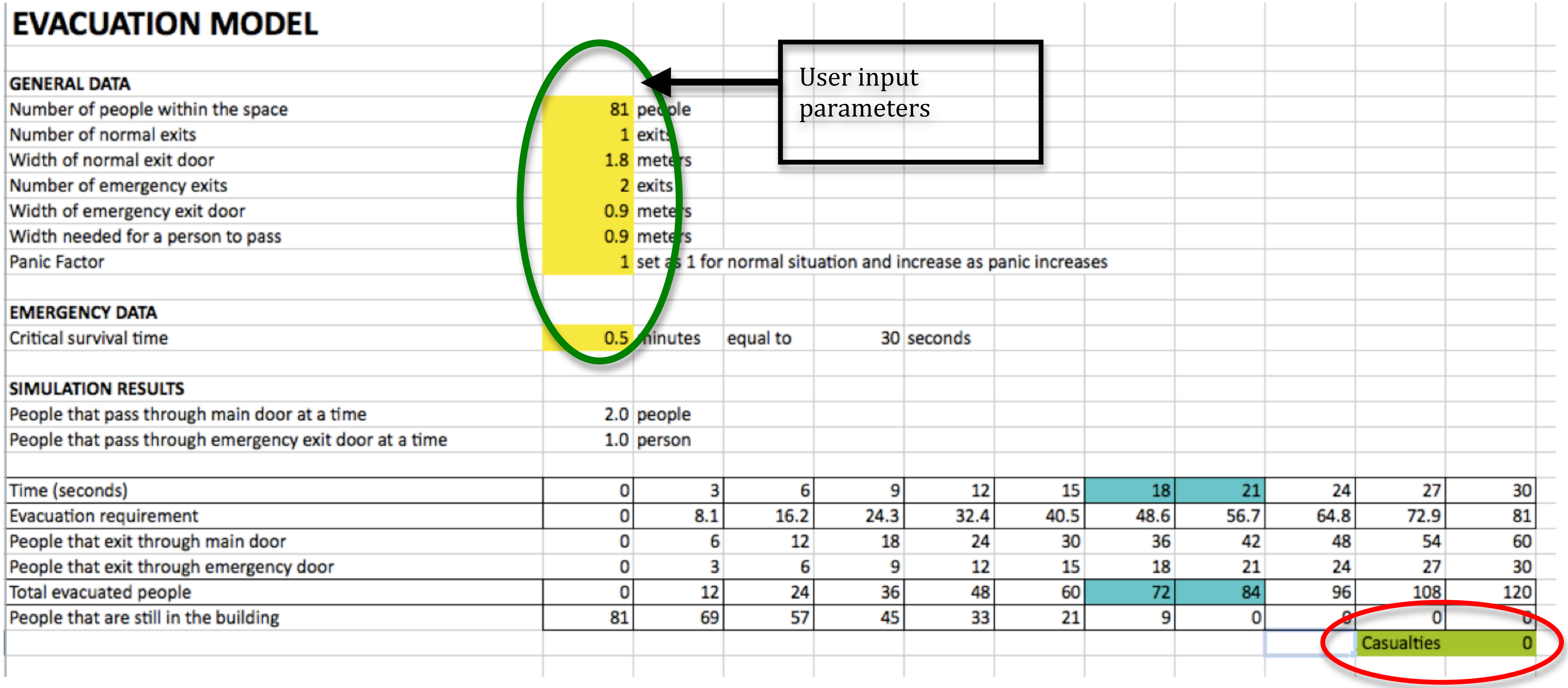
[35]*Smith J, 2010, Agent-Based Simulation of Human Movements During Emergency Evacuations of Facilities*



EVACUATION MODEL

GENERAL DATA		
Number of people within the space	81	people
Number of normal exits	1	exits
Width of normal exit door	1.8	meters
Number of emergency exits	2	exits
Width of emergency exit door	0.9	meters
Width needed for a person to pass	0.9	meters
Panic Factor	1	set as 1 for normal situation and increase as panic increases
EMERGENCY DATA		
Critical survival time	0.5	minutes equal to 30 seconds
SIMULATION RESULTS		
People that pass through main door at a time	2.0	people
People that pass through emergency exit door at a time	1.0	person

Time (seconds)	0	3	6	9	12	15	18	21	24	27	30
Evacuation requirement	0	8.1	16.2	24.3	32.4	40.5	48.6	56.7	64.8	72.9	81
People that exit through main door	0	6	12	18	24	30	36	42	48	54	60
People that exit through emergency door	0	3	6	9	12	15	18	21	24	27	30
Total evacuated people	0	12	24	36	48	60	72	84	96	108	120
People that are still in the building	81	69	57	45	33	21	9	0	0	0	0
										Casualties	0

Figure 21. Basic Excel Evacuation Model

9.5.1.1 THE ELEMENT OF PANIC

Panic is an interesting concept when speaking of fire evacuation scenarios. As mentioned before this variable was used in order to represent a decrease in the flow of people when exiting the building under an emergency situation. Many things have been said in literature about the element of panic or 'panic factor' making it a controversial topic.

Some authors of scientific articles such as Shi, Ren and Chen (2009) mention the use of a panic factor in their agent-based evacuation model for large public buildings under fire conditions. They speak of it as another contributing factor apart from the crowd density and place it as a variable of psychology or individual character since it reflects a physical and environmental situation of occupants and influences the movement speed as well.[36] In their scientific article they show a representation of the panic factor in terms of the mobility of the occupants and the increase in evacuation time. Several equations are given to show this application in what they called the AIEva computer model where they consider the panic level of occupants caused by fire as a function of danger.

An article from Means of Escape an online magazine on fire safety speaks on how companies such as BRE Global[37] that work to ensure that fire, security, environmental and other products and services provide the quality of performance and protection that they should have. "They certify fire and security systems and services against standards developed in cooperation with manufacturers and insurers. With extensive research program into human behavior in fire incidents and experimental evacuation studies they have developed unique knowledge and understanding of the factors controlling affecting escape behaviors important for the development of effective evacuation strategies."[38]

In their findings they have been able to distinguish that numerical models of the process of evacuation vary widely in their degree of sophistication. The simplest treat the population as a homogeneous fluid and concentrate on the flow capacity of the building. At the other extreme, there are detailed simulations where each person is treated individually, with explicit behavioral rules. Simpler models are easier to use and faster to run. However, realistic behavior is required for fully realistic results, although these are the most complex and difficult aspects of evacuation to simulate. Not all aspects of behavior are fully understood or quantifiable yet with the available tools researchers still strive to find the best representation.[38]

The more simplistic approach has been the one used for the analysis done in this thesis project in order to show the value and impact that human behavior can have in a stressful situation without increasing the complexity of the analysis.

Nonetheless, scientists have come to new findings with regards to the element of panic in fire situations. As Guylen Proulx from the Fire Risk Management Program Institute for Research in Construction of the National Research Council in Canada states "the first common expectation about human behavior in fire that should be dealt with is the

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[36] *Shi, Ren and Chen, 2009, Agent-based Evacuation Model of Large Public Buildings Under Fire Conditions, Beijing*

[37] *http://www.bre.co.uk/*

[38] *Modeling Human Behaviour and Evacuation in Fires, http://www.means-of-escape.com/articles/101/modelling-human-behaviour-and-evacuation-in-fires/*

assumption that during a fire occupants will panic. In retrospect, it is easy to point to some decisions that were not optimal and played a negative part on the outcome of a fire; however, at the time of the fire these decisions were rational when all factors are considered. ”[39] According to Proulx contrary to common belief, it appears that it is the lack of panic that characterizes most fires. In the initial moments of a fire, upon smelling smoke or hearing the fire alarm, it is often observed that occupants do not react, and deny or ignore the situation. This seems especially true in public buildings where occupants do not want to overreact to a false alarm or a situation that is already under control. Such avoidance or acceptance of a dangerous situation often results in delays in starting evacuation of a building or in taking protective action which can then result in a negative outcome.

As BRE Global research states, “a key to understanding human behavior is the observation that people rarely panic in fires.” They choose from a range of behaviors options depending on their assessment of the conditions. However as Proulx has mentioned in his research, in some cases their assessment may be incorrect. With the benefit of hindsight, it is easy to dismiss the person’s actions as irrational or panic.

The element of panic has not so much to do with people being irrational but with how complex peoples behavior actually is. It is because of this complexity that fire evacuation models and fire engineering is still far from being a perfected science. Since it can be determined then that occupants do not panic during fires, what is it that they do, since fire situations still end in casualties.

Proulx separates occupants behaviors into three major elements: a) the occupants characteristics, b) the buildings characteristics and c) the fire characteristics. These three elements interplay in the entire development and outcome of the event. Table 7 gives an example of some of the factors that have an impact on human behavior during a fire.

The occupants characteristics will be dominant in explaining and predicting the potential occupant behavior. This includes the profile of the occupant which groups parameters such as gender, age, ability and limitation in terms of mobility. Personality and decision-making styles of each occupant can be influential as well, some copy the reaction of other while others are prepared to take on a leadership role.

The architecture of the space is an important building characteristic. If the space is complex, it can have a major impact on occupant movement and on the possibility of finding an alternative way out if the familiar route is blocked.

Fire characteristics can also play an important role in the occupants’ response. During a fire, people perceive different cues from fire and their interpretation of the situation will change influencing their behavior.

The mixing and matching of all these characteristics makes the study of human behavior during a fire evacuation very complex and hard to predict. The concept of role can explain the lack of response of some occupants in public buildings. When occupants play a role of visitors they expect to be taken care of and social interaction will take place; people will be looking at what others are doing.

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[39] *Proulx, 2001, Panic Behavior, pp2, Munich*

Occupant Characteristics	Building Characteristics	Fire Characteristics
Profile • Gender • Age • Ability • Limitations	Occupancy • Residential • Office • Factory • Hospital • Hotel • Cinema • College and University • Shopping Center	Visual cues • Flames • Smoke (color, thickness) • Deflection of wall, ceiling, floor.
Knowledge and Experience • Familiarity with the building • Past fire experience • Fire safety training • Other emergency training	Architecture • Number of floors • Floor area • Location of exits • Location of stairwells • Complexity of space/way finding • Building shape • Visual access	Olfactory cues • Smell of burning • Acrid smell
Condition at the Time of Event • Alone vs. with others • Active vs. passive • Alert • Under Drug-Alcohol-Medication	Activities in the Building • Working • Sleeping • Eating • Shopping • Watching a show, a play, a film, etc	Audible cues • Cracking • Broken glass • Object falling
Personality • Influenced by others • Leadership • Negative toward authority • Anxious	Fire Safety Features • Fire alarm signal • Voice communication system • Fire safety plan • Trained staff • Refuge area	Other cues • Heat
Role • Visitor • Employee • Owner		

Table 7. Factors Having an Impact on Human Behavior in Fire

Conditions such as rapid spread of fire, limited known or available exits and a building being overcrowded do not necessarily lead to mass panic but they can certainly lead to a tragedy. Experts in the field of human behavior as mentioned before have concluded that occupants panicking in fires is usually a judgment made in retrospect, which does not consider the perspective of the person at the time of the event. All human behavior in a fire situation can be rationalized when the event is seen through the subject's perspective. The judgment that panic took place during a fire is very much influenced by the outcome of the fire.

Considering efforts are being invested in developing computer models to take into account the evacuation timing of buildings. Several occupational scenarios can be tested to obtain an array of egress times. The simulation of human behavior is not an easy task and simulating the movement of panicked people is possible even more difficult to accomplish due to the lack of data in the real world of occupants panicking during a building evacuation.

9.6 FIRE EVACUATION RISK ANALYSIS

Given the fact that combustion is a complex matter where dozens of solid, liquid or gaseous products can result in very complex fire situations. The existence of different materials that can react to one another make it very difficult to analyze a fire as one such phenomena. Hundreds of parameters are involved in a single fire such as the state of the combustible material, whether it was humid or dry, characteristics such as flammability points, is the fire confined or open, the ignition temperature, flammability limits, heat sources, external or natural factors, and many more. Therefore it can be said that there are no two fires alike, the plethora of possible reactions is a Pandora's box. There is not one absolute answer to a fire situation.[40]

As mentioned before, there are many variables that come into play when making a Fire Risk Analysis especially because of the randomness of the variables and the uncertainty this brings along.

To better understand fires that happen within buildings and their impact on human it is necessary to do a Fire Risk Analysis (FRA) that will later help in the development and setting of parameters and codes. The realization of an FRA is a simple engineering analysis that must include the subsequent steps:[41]

1. Select a result as an objective.
2. Determine the scenarios which can be product of that objective.
3. Evacuation calculations.
4. Analyze the impact of fire exposure.
5. Examine the uncertainty.

The first step indicates to select a result as the main objective for the analysis. In the case of most fire situations and for purposes of this analysis this objective will be set as: ***"seeking the balance between cost and profits including the reduction of the number of casualties and property damage***".

Once the objective has been establish the next step is to analyze different scenarios or situations that can lead to the previously determine undesirable result. Here the best guide is experience and common sense as well as information from previous disasters of a similar area as the one being studied. The scenarios must be made by taking into account the different levels of a fire and their impact on the occupants in order to make the evacuation calculations. The selection of different levels of fire situation is crucial for the validity of the analysis. Its purpose is similar as a structural analysis where it must be determined if the design will respond as it is intended under the specific challenge.

Therefore it is necessary to begin the analysis by determining the possible scenarios by defining three distinct types of fires:

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[40] *NFPA – Handbook, 2011, Section , pg 1-1*
[41] *NFPA – Handbook, 2011, Section 2, pg 2-15*

Type 1: Smoldering fires, where only smoke is generated;

Type 2: Non-flashover flaming fires, where a small amount of heat and smoke is generated; and

Type 3: Flashover fires, where significant amounts of heat and smoke are generated with a potential for fire spread to other parts of the building.

Human Exposure. It is hard to give specific data on the amount of time a human can survive when being exposed to a fire situation. As mentioned before there are so many factors that come into play that can affect the survival time of a person. It all depends on the concentration of smoke and the time the person is exposed to it but it can be said that a human can survive within a fire environment longer than in a smoke environment. For purposes of this analysis a critical survival time frame was estimated between 30 seconds and 2 minutes given the amount of people and the auditoriums area.

It should be mentioned that the models relating to occupants response and evacuation use four categories of occupants: seniors and children, occupants with special needs, able–body female occupants and able-body male occupants. When using specific computer models, different travel speeds can be assigned to each group which will lead to different results on evacuation times. The location of the occupants as well as the type of warnings (cues) they receive must too be taken into consideration.

In the case of an accident, the final outcome is not known in advance. Different outcomes can occur depending on the initial conditions of the event. The circumstances of the scenario at the time of the accident will decide the final outcome. In the risk analysis procedure it is often necessary to examine a large number of scenarios with different chains of events. Each final event, outcome or sub-scenario can be assigned a probability of occurrence as a consequence of the uncertainty in which event will actually occur. In order to structure the possible event sequences arising from an initial even, an event tree approach may be useful. It provides a logical graphic description of the possible final events and is therefore a rational method for quantitative risk analysis.[42]

The event tree describing an evacuation in case of a fire starts with an initiating event (the initial fire). Different installations or circumstances that will have an effect on the outcome can be treated as branch events. At each branch point different alternatives may occur. Each event tree outcome is evidence of the chain of events leading to the final event that is then compared to the main objective of the analysis.[43] Figure 22 shows an event tree for a simple fire risk analysis where variables such as the alarm, sprinkler and emergency doors are taken into consideration. The event tree structures the scenario so that the relevant questions for the analysis can be identified:

- What can happen?
- What is the probability it happening?
- What are the consequences if it does happen?

Different scenarios will be analyzed in the subsequent sections as well as their probability of occurrence and consequence. As mentioned before when stating the main

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[42] *Frantzich, 1998, Event Tree, pp 24*

[43] Frantzich, 1998, Event Tree, pp 24

objective of this analysis the consequence will be measured in terms of number of casualties and property loss.

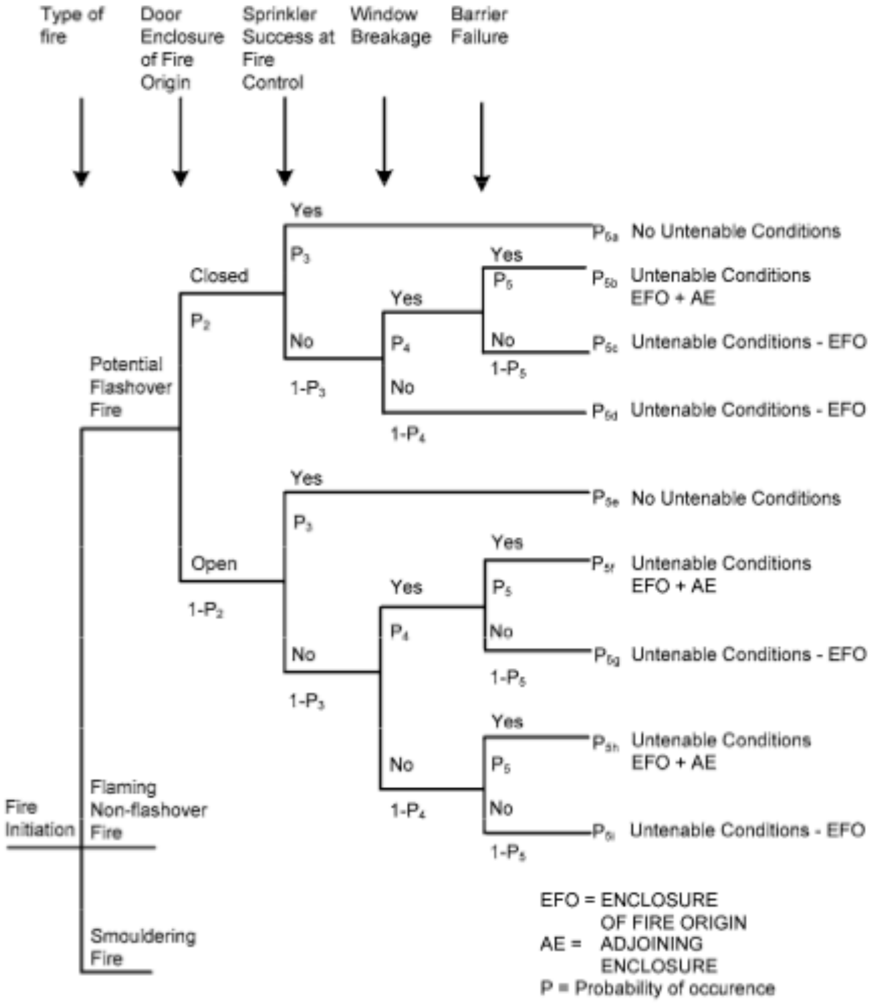

Figure 22. Event Tree for Fire Risk Analysis Example[44]

During any fire situation the existence of circumstances that one is incapable of fighting will rise, these circumstances are known as untenable conditions. For FRA untenable conditions can be defined as escape routes filling up with smoke in combination with other factors such as smoke temperature and toxic gas concentration. The problem though, lies with defining these lethal conditions. People are not equally sensitive to fire conditions and factors such as age, sex, and physical and psychological health status play an important role. Therefore, untenable conditions are defined as soon as the conditions are fulfilled, and it is assumed that for example the escape route is instantaneously blocked. Otherwise the analysis can become very lengthy and complicated.

The values for the different variables included in a FRA such as the response and behavior time are known as deterministic values. There are no calculation models available to determine them and like this one many other values are not easily determined and may be subject to uncertainty. For design purposes, values should be

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[44] *Fire Safety Engineering, 2005, ISO 16732*

chosen to represent the credible worst case. If only one consequence value, such as the number of casualties is calculated for each scenario the use of computer tools is normally straightforward and this is the normal situation in building design. Nonetheless, this might not be the best way to go but for now is the one that has proven to have the better outcomes and for that fire safety engineering is still along way from becoming a complete science.

The event tree from figure 22 shows the potential sub-scenarios that could give rise given the type of fire being described. Nonetheless, for purpose of this example not all relevant variables were taken into consideration such as the sprinkle systems, window breakage and barrier failure since that would only complicate the example. The general idea of what would happen given the type of fire will be described and the consequence of it in terms of number of casualties.

9.6.1 Evacuation Scenarios

The scenarios that will be analyzed in this section will describe highly unfavorable possible cases in order to better represent the importance of having specific safety components in order to diminish the severity of the outcome.

Scenario 1: Electrical Fire due to a Short Circuit in Stage Lights (Type 1 or 2)

Taking the same example of an auditorium that has been used all throughout this chapter, with a variation in the number of occupants where in fact 100 people mostly fill the auditorium. Still having one main exit and two emergency exits; a situation where a short circuit in one of the stages lights gives rise to an electrical fire can lead to the following events.

Usually short circuit fires can be prevented but in this scenario the electrical current overload leads for a spark to jump from the electrical wires and start a flame. This type of flame could easily be contained but in this case the flame reaches the stages curtain which has been rolled up and is hanging close to where the flame started. The flame reaches the cloth of the curtain and in no time the entire curtain is burning rapidly. This increase in the flames also increases the dispersion of the fire and the creation of smoke. By this time the fire alarm has gone off and people have started to evacuate the auditorium. It looks like the fire is being contained on the upper level since it is the lifted curtain, which has been ignited. People will still be able to evacuate through the main auditorium door and technically through the two emergency exits.

Nonetheless, the curtain starts to fall apart and pieces of ignited cloth start to fall onto the stage area, specially the back stage area where many props and customs are located. All of these items made out of extremely combustible materials, which indeed in no time catch fire as well. The situation has become a bit more dangerous and threatening since the area behind the stage has completely been engulfed with flames making it very difficult to use one of the emergency exits located near the stage area which too has started to create a dense cloud of smoke making it hard for the occupants to see and specially breath. Even tough the second emergency exit is clear of debris it is locked from the outside, which means that there is only one possible exit route and that is through the main door leading to the corridor.

Figure 23 shows the representation of this scenario and the effects of such elements taking place on the main objective of this risk assessment (the minimization of number of casualties).

The representation of 100 occupants within the space in question, two emergency exits blocked and a roaring fire on the stage area, it has been determined for purposes of this example that the panic level of this situation is of a level 5 given that only the main door can be used to exit, but this door leads straight into a corridor making very hard for people to flow therefore causing some blockage by the door area.

Since the fire is mainly located on the stage area and no doors can be used all the occupants must move from their seating location to the back door which is already very congested. This situation will only increase the total evacuation time and having a critical survival time of around 3 minutes (determined by common sense, since the fire is mainly contained in the front of the auditorium with the smoke rising to the high sealing's) the model shows that there will be 28 casualties in set scenario.

The main influential factors in this scenario that lead to the increased number of casualties can be said to be the fact that non only one but the two emergency exits where blocked, there was an increase in the number of occupants (even though they where still well within the occupancy level limits), the main door leaded to a confined corridor creating clutter and congestion slowing down the evacuation. Most of the times the casualties that are caused by emergency situations such as this one are due to the lack of air circulation and increase levels of toxic fumes. More often than not the toxic smoke and fumes are the leading cause of death and not the flames itself.

This scenario leads to unacceptable results with regards to the main objective of diminishing the number of casualties. But it showed the importance of not only having some safety systems in place but actually have them work properly. For example, making sure that all emergency exits are unlocked, that there is a workable fire alarm system as well as a sprinkler system, checking the design of the area as to see potential problems such as the fact that the main door leads to a corridor and not an open space, etc.

EVACUATION MODEL

GENERAL DATA		
Number of people within the space	100	people
Number of normal exits	1	exits
Width of normal exit door	1.8	meters
Number of emergency exits	0	exits
Width of emergency exit door	0.9	meters
Width needed for a person to pass	0.9	meters
Panic Factor	5	set as 1 for normal situation and increase as panic increases

EMERGENCY DATA					
Critical survival time	3	minutes	equal to	180	seconds

SIMULATION RESULTS		
People that pass through main door at a time	0.4	people
People that pass through emergency exit door at a time	0.2	person

Time (seconds)	0	18	36	54	72	90	108	126	144	162	180
Evacuation requirement	0	10	20	30	40	50	60	70	80	90	100
People that exit through main door	0	7.2	14.4	21.6	28.8	36	43.2	50.4	57.6	64.8	72
People that exit through emergency door	0	3.6	7.2	10.8	14.4	18	21.6	25.2	28.8	32.4	36
Total evacuated people	0	7.2	14.4	21.6	28.8	36	43.2	50.4	57.6	64.8	72
People that are still in the building	100	92.8	85.6	78.4	71.2	64	56.8	49.6	42.4	35.2	28
										Casualties	28

Figure 23. Scenario 1 – Short Circuit in Stage Lighting

Scenario 2 – Fire on Center Seating Area Due to an Explosion in Adjacent Room (Type 3)

The auditorium being analyzed is located within the premises of a pharmaceutical company and adjacent to one of its research and testing laboratories. In one of their chemical tests a combination of elements make it so that an explosion occurs and spreads rapidly not only within the lab but breaks through the wall that separates the lab from the auditorium. In the moment of this event, a conference is being held in the auditorium and it is filled to its maximum capacity of 108-seated spectators and 3 speakers on stage.

The emergency fire systems installed within the laboratory immediately start to act in hopes of containing and controlling the fire. Nonetheless, the explosion has been of such magnitude that there is fire already spreading within the seating area of the auditorium. There are several resulting casualties from the explosion itself, which will not be taken into account in this scenario analysis. Everything happens so suddenly and unexpectedly that chaos and panic spread rapidly within the auditoriums occupants. People start jumping over the seats instead of walking through the corridors; they start pushing and shoving trying to reach an exit. Casualties from the explosion itself make it a more stressful situation and there are toxic fumes in the air resulting from the chemical mixture that caused the explosion and these fumes greatly diminish the survival time of a person inhaling them.

Figure 24 shows the evacuation analysis for this particular situation. The occupant number was set to a total of 100 people to keep the consistency between scenarios with all exits open at the time of the emergency. Nonetheless, the panic factor was drastically increased since the explosion made the occupants behavior be more erratic and chaotic because of the explosion. Something very important of this scenario is the fact of the existence of toxic fumes due to the chemical reaction that went wrong in the adjacent laboratory. This fumes can greatly diminish the survival time and combined with an increase in panic can greatly impact the survival rate of the occupants. As the model in figure 24 shows, given this situation and the parameters described, 25 people are unable to evacuate the area.

This scenario is a very dramatic one which takes the evacuation analysis to its limit, but by doing so it can be easily represented how important safety measures and evacuation procedures are in order to guarantee the safety of public building users. For that, and by means of studies such as this one, codes and specifications have been created to better increase the probability of survival and diminish the loss of lives during and emergency situation.

The evacuation model can graphically display the existing flow and compare it to the control, which was taken from the fire drill analysis of section 9.4. By means of comparing this two variables it is possible to graphically see the impact an emergency situation can have over an evacuation. Figures 25 show the difference between the evacuation time and number of people evacuated in a control environment compared to an emergency situation and figure 26 displays the number of evacuated people for a specific survival time displaying the number of casualties for set situation. These graphics will change accordingly to the data being analyzed.

EVACUATION MODEL

GENERAL DATA		
Number of people within the space	100	people
Number of main exits	1	exits
Width of main exit door	1.8	meters
Number of emergency exits	3	exits
Width of emergency exit door	0.9	meters
Width needed for a person to pass	0.9	meters
Panic Factor	12	set as 1 for normal situation and increase as panic increases

EMERGENCY DATA					
Critical survival time within area of fire	3	minutes	equal to	180	seconds

SIMULATION RESULTS		
People that pass through main door at a time	0.2	people
People that pass through emergency exit door at a time	0.1	person

Time (seconds)	0	18	36	54	72	90	108	126	144	162	180
Evacuation requirement	0	10	20	30	40	50	60	70	80	90	100
People that exit through main door	0	3	6	9	12	15	18	21	24	27	30
People that exit through emergency door	0	1.5	3	4.5	6	7.5	9	10.5	12	13.5	15
Total evacuated people	0	7.5	15	22.5	30	37.5	45	52.5	60	67.5	75
People that are still in the building	100	92.5	85	77.5	70	62.5	55	47.5	40	32.5	25
										Casualties	25

Figure 24. Scenario 2 – Chemical Explosion in Adjacent Room

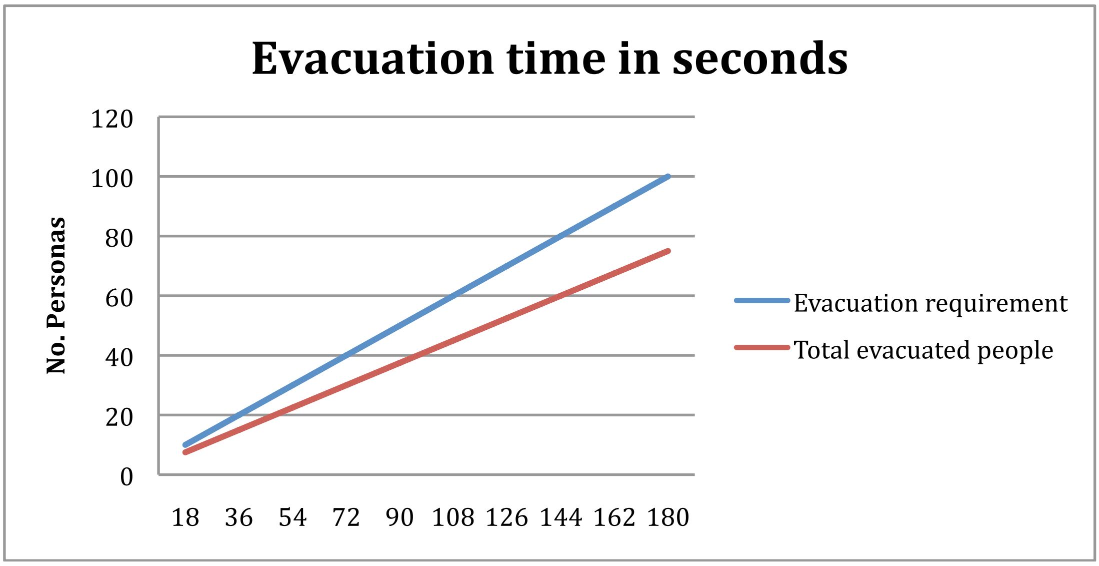

Figure 25. Evacuation in time (s.) for Scenario 2

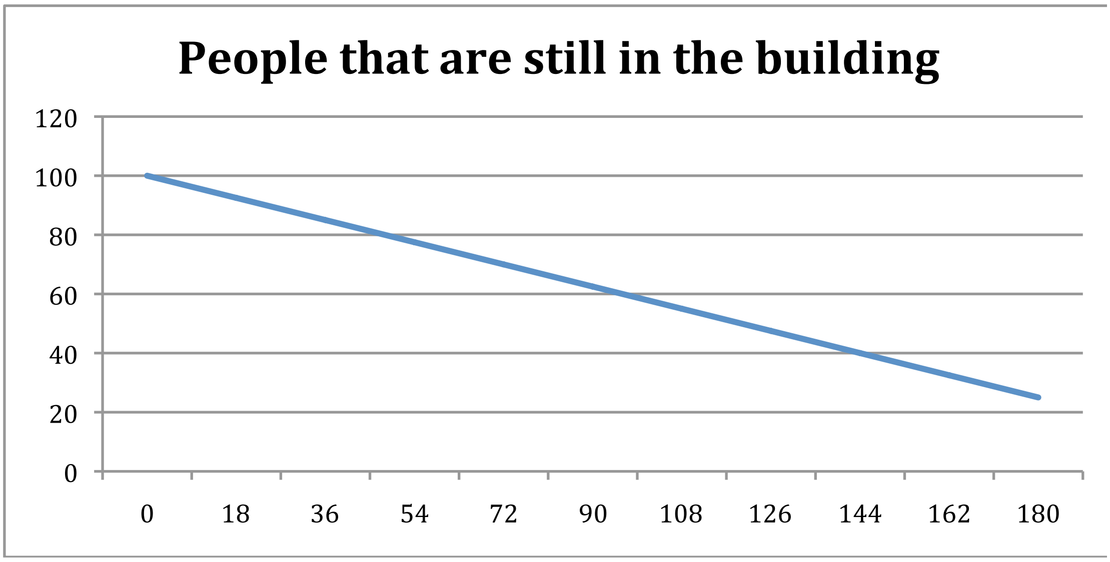

Figure 26. People Remaining in the Building at a Given Time (s)

Scenario 3- Adding an Extra Emergency Exit Door

In this third scenario the same situation as in scenario two will be analyzed but with the existence of one extra emergency door. The addition of one more emergency exit door located on the opposite side of the stage would have a major impact towards accomplishing the FRA objective. Figure 27 shows the location of the additional emergency exit door.

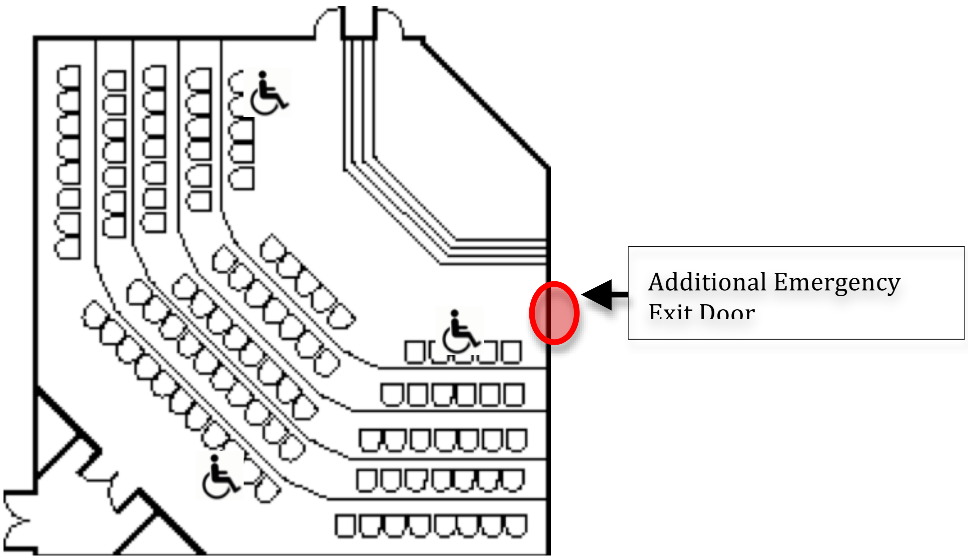

Figure 27. Additional Emergency Exit Door

By means of adding an additional emergency exit at the opposite side of the auditorium it is possible to diminish the number of casualties from 93 to 3; a great advantage towards achieving the FRA objective. As figure 28 demonstrate in the data the existence of another mean of egress could greatly influence in the survivability of the occupants. The panic factor was lowered in order to simulate the re-distribution of occupants that would exit through each of the existing doors. The probability of clutter and congestion will too be lowered and by that make it possible for the people to exit under the critical survival time.

Under a cost benefit analysis the cost of adding an additional exit door compared to the dramatic decrease in the number of casualties given an extreme situation such as the one being depicted in this scenario could be justified but should be fully analyzed before making that decision. Even if its probability of occurrence is particularly low, the additional door in any case will be beneficial. By adding the extra door and analyzing the situation of scenario 1 (having a higher probability of occurrence) the number of casualties could be reduced to zero. Given that the probability of occurrence for this scenario may be so small and not justify the costs of adding an extra door it is very important to go through a fire risk assessment as well as an evaluation to verify if indeed the area in question complies with all safety measures required by the NRD-2 and other safety building codes.

Building Codes and Safety Codes demonstrate the importance of having analyzed the different scenarios of a particular site. In the example of the auditorium used for these scenarios, a building safety regulation would notice the lacking of that third emergency exit door (if this indeed would be the case) and would have such building plans fail the safety inspection since it is stated by them that all exits should be equally located within the space in question.

Nonetheless, as mentioned before there is a lack of fire safety engineering data that would greatly aid in the field of fire safety for buildings since it is usually difficult to obtain data forming to form new knowledge. The reason for this is that much data can only come from post-fire investigations. Information's on human responses and actions in actual situations can only come from this type of investigation. Performing experiments may not provide an alternative for ethical reasons. Care must thus be taken to use as accurate data s possible, and to not use small samples to update the prior data. In fire safety engineering, many of the parameters still have to be subjectively estimated with little statistical support.[45]

[45] Frantzich, 1998, Fire Safety Engineering Data, pp 59

EVACUATION MODEL

GENERAL DATA		
Number of people within the space	183	people
Number of main exits	1	exits
Width of main exit door	1.8	meters
Number of emergency exits	3	exits
Width of emergency exit door	0.9	meters
Width needed for a person to pass	0.9	meters
Panic Factor	5	set as 1 for normal situation and increase as panic increases
EMERGENCY DATA		
Critical survival time	3	minutes equal to 180 seconds
SIMULATION RESULTS		
People that pass through main door at a time	0.4	people
People that pass through emergency exit door at a time	0.2	person

Time (seconds)	0	18	36	54	72	90	108	126	144	162	180
Evacuation requirement	0	18.3	36.6	54.9	73.2	91.5	109.8	128.1	146.4	164.7	183
People that exit through main door	0	7.2	14.4	21.6	28.8	36	43.2	50.4	57.6	64.8	72
People that exit through emergency door	0	3.6	7.2	10.8	14.4	18	21.6	25.2	28.8	32.4	36
Total evacuated people	0	18	36	54	72	90	108	126	144	162	180
People that are still in the building	183	165	147	129	111	93	75	57	39	21	3
										Casualties	3

Figure 28. Scenario 3 – Additional Emergency Exit Door

9.6.2 Expected Value Probability Analysis

In order to conclude the Fire Risk Analysis of the auditorium, different probabilities of occurrence can be assigned to each scenario in order to find its expected value with regards to the number of casualties of that auditorium. What this means is that by setting different probabilities of occurrence to each scenario and multiplying them by their consequence or number of casualties each situation displayed a total expected value of casualties for that auditorium given the scenarios analyzed is obtained. Only scenarios 1 and 2 will be compared towards each other since scenario 3 has different conditions such as de addition of an extra door. As it has been mentioned before, for an analysis to be fully reliable many more scenarios and data must be analyzed but for purposes of this thesis it is enough to represent the importance of the calculations with a much smaller sample.

The following equations were taken into consideration when calculating the expected value for the fire risk scenarios.

Risk = Σ f(frequency x consequence of a given scenario), for all scenarios.

Risk = Combined frequencies of all scenarios where the consequences exceed the specified safety threshold.

SCENARIO	Fire type 1	Fire type 2	Fire type 3	
CASUALTIES	28	25	25	
PROBABILITY	0.22	0.54	0.24	
Exp. Value	6.16	13.5	6	25.66

Table 8. Expected Value

Table 8 shows the Expected Value when giving the scenarios probabilities of occurrences of 22%, 54% and 24% respectively. These probabilities of occurrence are based on statistical data gathered by fire departments in Canada.[46] In Canada, statistics show that the probability of fire starts in public buildings is of 7.68×10^{-6} per m^2 given that this number takes into consideration the existence of other safety measures that are able to reduce the number of casualties. In this situation, given the scenarios analyzed in the previous section, it can be expected that at least 26 people will loose their lives during a fire emergency in the auditorium in question in one given year.

[46] *Fire Engineerign, 2005, A.6.3. Characterization of Probabilit, pp27*

The probabilities for some other parameters given that the type of building in question does not resemble a typical one which can be found on the building codes should be obtained from engineering judgment.

It is not simple to achieve a fire safety design because computer tools have become available but because the problem lies in that no acceptable design values have been derived and there is no standard practice in the area of fire safety engineering apart from following the existing codes.

As building codes now allow engineering solutions to the design objectives these solutions have become more frequent. One particular problem in fire safety engineering design is the lack of acceptable design values, which forces the engineer to choose these values on their own judgment. Occupant safety will then be determined by the experience and the skill of the engineer. As the values used for design will be subjectively chosen, the resulting risk level will be unknown.[47]

9.6.2.1 Decision-Making Parameters

Scenario fire risk is then calculated as probability times consequence for each scenario and it can be measured in life loss and property damage. This is used as a decision-making parameter called expected risk to life (ERL). When taking into account the property damage this too can be used as a decision-making parameter known as fire cost expectation (FCE).

ERL is the expected number of deaths per year as a result of fire in the subject building. FCE is the expected total fire cost, which includes the capital cost for passive and active fire protection systems, the maintenance and inspection costs for the active fire protection system, and the expected losses resulting from fire in the building.

The separation of life risks and protection costs eliminates the difficulty of assigning a monetary value to human life and allows for a separate comparison of risks and costs. The ERL valua can be used to determine whether a fire safety design meets the performance code requirements, or whether it provides a level of safety that is equivalent to that of a code-compliant design in a prescriptive code, whereas the FCE value can be used to identify cost-effective designs.[48]

[47] *Frantzich, 1998, Fire Safety Engineering Data, pp 140*
[48] *Fire Engineering, 2005, A.6.5. Calclaton of scenario fire risk and combined fire risk, pp 32*

10 BUILDING EVALUATION

Building permits are issued after the building department reviews the building plans for compliance with the applicable code. When a property owner wants to build a new building, remodel a building or build an addition on to an existing building, he or she must obtain a building permit from the local jurisdiction. A set of plans drawn by an architect or engineer is submitted to the building department showing the type of work that will be done on the project and the drawings must then be reviewed to determine whether or not the plans comply with the adopted code. If they do so, then a building permit will be issued to the contractor. The contractor is required to keep the permit on the job site for the inspectors as the job progresses.[49]

Within the International Building Code there is a clause known as the grandfather clause or grandfathering. This clause states that "existing buildings are permitted to continue without change as long as they are maintained in accordance with the code under which they were constructed." Nonetheless, in Guatemala even though each building is built under strict regulations they cannot be grandfathered since those regulations have not been adopted by the national government. The fact that existing buildings cannot be grandfathered means that all buildings of public use must be evaluated in order to see if they comply with what is stated by the NRD-2.

A group of experts on the subjects must be the ones evaluating the different aspects of the building that must comply with the NRD-2. To do so an evaluation committee has to be form and it shall be made up of licensed architects and professional engineers with expertise in specialized fields such as civil, structural, fire protection, and mechanical engineering.

The evaluation process culminates with the issuance of technical reports that, because they directly address the issue of code compliance are extremely useful to both regulatory agencies and building-product manufacturers. Agencies use evaluation reports to help determine code compliance and enforce building regulations; manufacturers use reports as evidence that their products meet code requirements and warrant regulatory approval.

10.1 The Report Process

The report process will begin when a company submits an application for an evaluation report. Then a member of the technical staff will be assigned to evaluate the data and work with the applicant to make sure compliance is proven, before a report is issued, with either the building code or an acceptance criteria. Once the applicant has satisfactorily answered all questions rose by the evaluation committee, and has fulfilled other applicable requirements, and evaluation report must be issued. New reports will be issued for one year, after which they are re-examined and may be reissued and one or two year intervals, depending on the applicant's performance.

By means of an evaluation:

- A building regulator can be told about his products, systems and materials or methods that are code-compliant.

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[49] *Thomas, 2009, Permits, pp 13*

- For a manufacturer a report will make it easier to market his building related product, because he will have solid evidence that the product meets code requirements.
- For a designer, architect or contractor an evaluation will work as evidence for local building officials that they are using code-complying materials.
- Members of the general public will also benefit from the evaluation since it will promote public safety in the built environment.

The evaluation report must hold the following information (the complete evaluation format can be found in Appendix B of this thesis):

The evaluation starts by stated the business' name and date of update as well as some general information of the facility in question. Such information will include:

- The facility owners name as well as its contact information, including telephone number and e-mail.
- The tenants name and contact information;
- Name and contact information of evaluator;
- Evaluation elaboration date;
- The buildings name and address.

The person responsible for the evaluation will have to sign and stamp as well as the competent authority.

Next, the evaluator will have to mark certain aspects that will describe the facility being evaluated. Such aspects include the type of building or facility being evaluated and whether it consists of a new, existing or under construction building.

The occupancy load is the first aspect that will help determine whether or not the building or facility complies with the NRD-2 safety requirements. For that the evaluator must fill in the number of levels the building in question has and what level is currently being evaluated. Safety related questions will have to be marked within the evaluation format, questions with regards to fire safety measures, escape routs and emergency exits will be addressed.

A section has been included which has to do with the identification of internal threats with regards to the structural conditions, electrical equipment, gas, hydraulics and sanitary equipment as well as the condition of the furniture. A section for indicating the existence of external threats has also been included.

In order to calculate the total load capacity per Area a thorough description of the area in question must be captured. In order to do this the evaluation format allows the evaluator to mark certain details that can be seen within the area in question that will influence the load capacity. Such details include the number and type of seats found within the area, the existence or not of maximum load capacity signs, the measurements of existing emergency exits and distance between exits and the description of the existing doors. Elements including corridors and stairs are also addressed in this section.

When stairs are presents within the area being evaluated it is necessary to take notes on the type of handrails being used. The evaluation format gives several options for the evaluator to choose from and mark with regards to what he sees in the field. Also, the evaluation holds information on emergency ramps, isle widths and sign locations that have to be filled in by the evaluator with regards to what he or she seats whitin the area in question. Other aspects that form part of the evaluation format are with regards to the alarms and communication systems being used. Available space is given to draw diagrams indicating the location of the emergency exits, signs and alarm systems within the area under evaluation. Figures 29 and 30 are direct screenshots of the evaluation format being described. The complete evaluation format can be found in Appendix B of this thesis.

Threat Identification
Mark with an X
Internal Threats

Structural Conditions				Electrical equipment in poor condition					Location of gas instalations			
Wood in poor condition	Fractures Columns	Broken windows	Cracked walls and floors	Switches	Lamps	Control Telephone	Air Conditioning	Water Heater	Cilinders	Stationary Tanks	Oven Pilot	Gas Pipe

Hydraulics in poor condition				Sanitary in poor condition				Furniture in poor condition			
Water Pipes	Toilets	Water Tanks	Cisterns	Drainage	Sewers	Records	Drains	Chairs	Desks	Shelves	Records

Others :

Threat Identification
Mark with an X
Internal Threats

Structural Conditions				Electrical equipment in poor condition					Location of gas instalations			
Wood in poor condition	Fractures Columns	Broken windows	Cracked walls and floors	Switches	Lamps	Control Telephone	Air Conditioning	Water Heater	Cilinders	Stationary Tanks	Oven Pilot	Gas Pipe

Hydraulics in poor condition				Sanitary in poor condition				Furniture in poor condition			
Water Pipes	Toilets	Water Tanks	Cisterns	Drainage	Sewers	Records	Drains	Chairs	Desks	Shelves	Records

Others :

Figure 29. Screenshot of Evaluation Format (Threat Identification)

Total Load Capacity per Area

Indicate the quantity when needed or just mark with an X.

Levels #

Area*

Number of fixed seats	Nimber of none fixed seats	Maximum capacity (quantity)	Signaling of Maximum Capacity (mark with an X)		Emergency Exits (indicate quantity)				Doors (indicate quantity)										
			YES	NO	Total width (cm)	Minimum distance between exits	Maximum distance between exits	Exiting by means of other rooms	With Hardware	Without Hardware	With Signs	Without Signs	With rests	Without Rests	< 90 cm in with	< 203 cm in hight	Rests longitude < 110 cm	≥ 203 cm in height	Rests long > 110 cm

Corridors (quantity)				Stairs																
				With occupancy loads less than 50 (show quantity)				With occupacy loads higher that 50 (show quantity)				Antislipping surface (mark with an x)		Free height till roof (quantity)		Footprint (quantity)		Riser (quntity)		
					Rest		Rest		Rest		rest									
< 90 cm wide	≥ 90 cm wide	< 210 cm high	≥ 210 cm high	< 90 cm wide	Long < its width or 110cm	≥ 90 cm wide	Long ≥ de its width or 110 cm	< 110 cm wide	Long < its weidth or 110 cm	≥ 110 cm wide	Long ≥ its width or 110 cm	YES	NO	≥ 203 cm	> 203 cm	> 28 cm	< 28 cm	> 10 cm	> 18 cm	< 18 cm and >10 cm

Emergency Ramps

Indicate quantities

Occupancy loads smaller than 50		Occupancy load larger than 50		Ramps slopes						Rests for inclines of 150 cm						Rests in doors adjecent to ramps	
				Wheelchair accesible			Not wheelchair accesible			Superior and immediate			Inferior				
< 90 cm wide	≥ 90 cm wide	< 90 cm wide	≥ 90 cm wide	8.33%	> 8.33%	≥ 8.33%	12.50%	> 12.5%	< 12.5%	150 cm of length	< 150 of length	>150 of length	183 cm of length	< 183 of length	>183 of length	< 106 cm	≥ 106 cm

Aisle width

Indicate quantities

With fixed seats			Convergence of two aisles	With stars and seats on both sides			With staris and seats on one side			Sub-divided with handrails			Flat or with ramp and seats on both sides			Flat or with ramp and seats on one side		
12.5 % incline	< 12.5 % incline	> 12.5 % incline		122 cm	< 122 cm	> 122 cm	90 cm	< 90 cm	> 90 cm	58 cm	< 58 cm	> 58 cm	106 cm	< 106 cm	> 106 cm	90 cm	< 90 cm	> 90 cm

Figure 30. Screenshot of Evaluation Format
(Load Capacity and Emergency Ramps)

Part F: SINGLE CASE STUDY

In this final section a single case study will be evaluated. It consists of the September 30, 2011 exposition center fire in Guatemala. It will touch upon the safety criteria evaluated by the NRD-2 and whether or not the Expo Center counted with the necessary safety requirements in order to operate as such. This study bring to an end the research that took place in order to fulfill the requirements of this thesis project.

11 TIKAL FUTURA EXPO CENTER FIRE

On September 30th, 2011 at approximately 13:30 a fire broke inside the Guatemalan Expo Center known as Tikal Futura. Preparations where going on for its opening on October 1st to celebrate "Children's Day," a Guatemalan holiday. The fire is believed to have started by means of a short-circuit or system failure of the electric motor or air compressor in charge of delivering air to an inflatable slide. The wind generated by the compressor caused the fire to spread and ignite the windows curtains causing the complete combustion of the slide and other equipment.

The fire was controlled by the Expo Centers maintenance staff through the use of fire extinguishers located in the respective area, also counting with the support from the administrative staff and other resources of the area for this kind of event. In addition, the firefighters present and located outside the Expo Center chose to break the windows in an attempt to release the amounts of smoke that was accumulating in the room, thus preventing people from gas poisoning from the amounts of smoke in the air caused by the fire. All of the assembly staff that were inside the Expo Center at the time of the fire was safely evacuated without the need to report any victims due to the accident.

Figure 31. Tikal Futura Expo Center Fire, Guatemala

In order to verify the existence of safety measures at the time of the incident an evaluation was made to the area in question. All safety aspects with regards to the NRD-2 were taken into consideration at the time of the evaluation and the following were the findings.

11.1 Area Distribution

The following image shows the way different elements were distributed around the convention center. The activity that was going to be held there had to do with the celebration of “Children’s Day” and therefore would be entertaining a large amount of kids. For that there were three inflatable slides installed as well as an electric worm and an electric train. As for other equipment, there were several sound systems installed and electrical lighting and the entire area was surrounded by curtains.

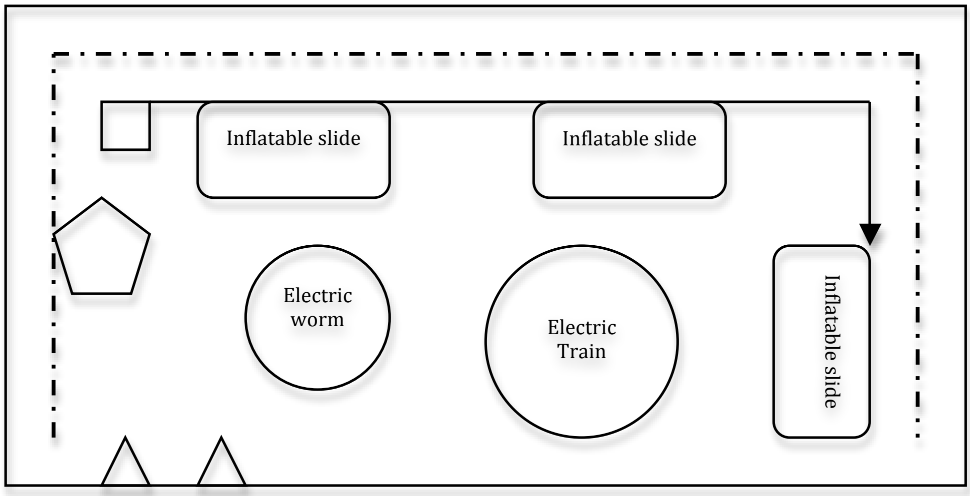
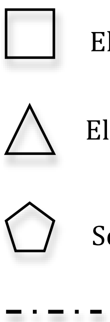


Figure 32. Area Distribution

Symbols:



Electric Motor

Electric Lighting

Sound System

Curtains

11.2 Responsible Authority

As stated by Article 2 of the NRD-2 in order to comply with the norm the property in question must count with a well defined and established responsible authority that in the happenings of an event can be held accountable. In the case of the Tikal Futura Expo Center, the responsible authority is the corporation itself, with Mr. Jose Antonio Mendez, General Manager as one of the leading personnel. In the case of failure to comply with the safety regulations it is he who would be held accountable. This is very important since for a norm to be able to work and ensure its implementation someone has to be held accountable in case something goes wrong. This person can even be charged with negligence in the case of human loss.

11.3 Safety Criteria Calculations

The Expo Center measures 50 meters by 40 meters and it counts with 4 emergency exits made out of double doors, two located at the north and south parts of the room and two single emergency exits one on each of the east and west sides. Figure 33 shows a mock version of the expo centers floor plans. The real floor plans can be found on Appendix C of this thesis and they were obtained from the original report made by the fire department that was at the scene. Nonetheless this mock plan illustrates the area in order for the reader to better understand the calculation that went into the safety analysis.

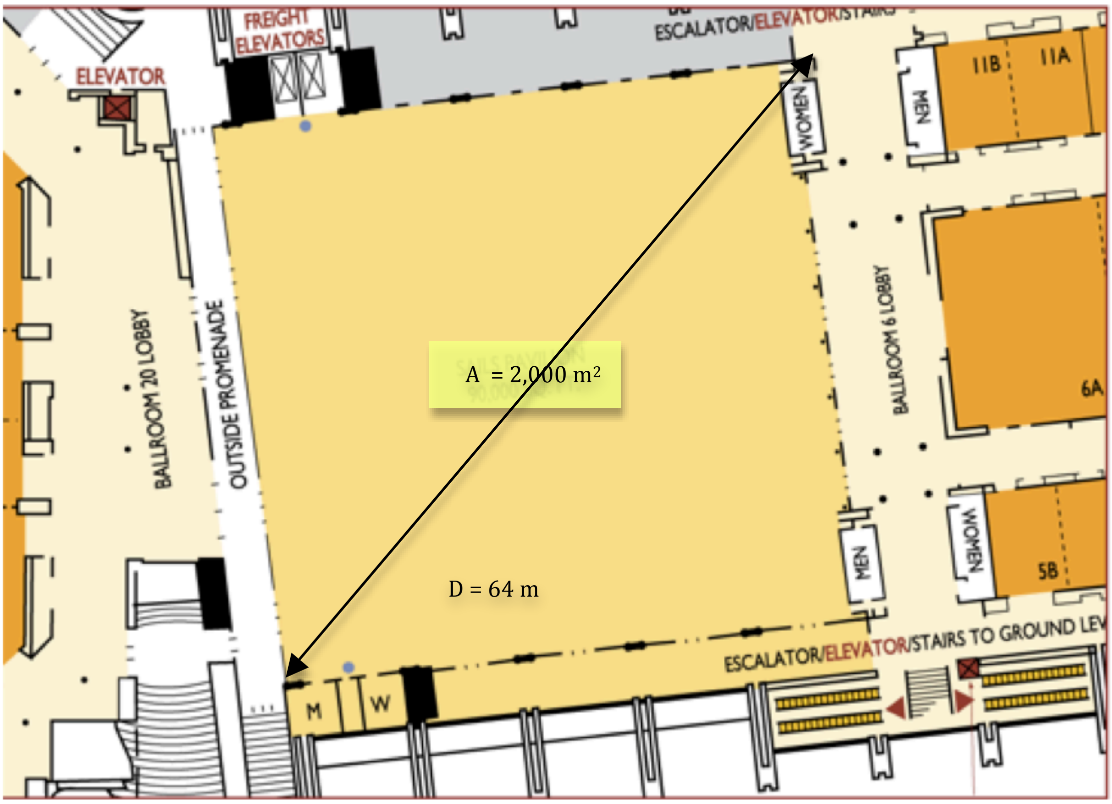


Figure 33. Expo Center Mock Floor Plan

As the calculations explained in section 8 of this thesis, the same took place in order to evaluate this area.

Step 1: Determining the Occupancy Load

Article 10a: For areas that do not hold fixed seats, the occupancy load can't be less that the floor area (square meters) divided by the factor indicated in table 1. When the structures use/type is not specified in table 1, it must be calculated using the type that seems most likely to its real use. For buildings or part of buildings with multiple uses, the occupancy load must be calculated with the one that results from the larger number of people.

Table 1: Convention Center, Load Factor = 1.39
Floor area = 50m x 40m = 2,000m^2
Occupancy Load = 2,000/1.39 = 1,439 people

Step 2: Determining the minimum number of Emergency Exits

Article 13: Every building or its utilized part must count with at least one emergency exit. No less than two when it is required by table 1 and additional exits when:

a) Each lever or its part with an occupancy load larger than 1,000 people must have at least four emergency exits.

Occupancy Load = 1,439 → minimum of 4 exits
Number of Emergency Exits seen on site = 6 → OK

Step 3: Determining the total width of the Emergency Exits

Article 14: The total emergency exit width in centimeters, will not be less than the occupancy load multiplied by 0.76 for stairs and 0.50 for other types of emergency exits, nor will it be less than 90 centimeters. The total width for emergency exits must be equally divided between all emergency exits and the maximum width of required emergency exits of any level must be kept throughout the entire building.

In the Expo Center having 4 double emergency exits measuring 180 cm each and two single exits of 90 cm each a total width of 900 cm is obtained by means of all exits. According to what is stated on the NRD-2 and by calculations made on the text box below the needed width of emergency exits to cover the entire floor space of the expo site is of 719.5 cm and having 900 cm worth of exits it can be determined that the space complies with more than the minimum requirement of the NRD-2.

6 Double Exits = 180 cm each = 720 cm
2 single exits = 90 cm each = 180 cm
Total Emergency Exits = 900 cm
Width of Exits = 1,439 x 0.5 = 719.5 cm < 900 cm → OK

Step 4: Emergency Exit Location

Article 15: When three or more exits are required, at least two of them bust be located with a separation measured by a straight line between them of no less than half the distance of the largest diagonal of the building or area to be evacuated. The additional exit(s) must have an adequate separation between them, so than if one of them is blocked the others remain available for evacuation.

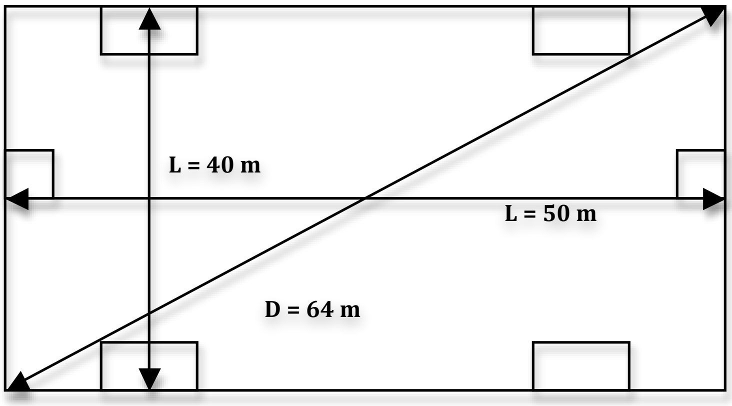


Figure 34. Emergency Exit Location

Minimum distance between Exits = 64/2 = 32 m
Distance in plans = 40 m > 32 m → OK

11.4 Signs

After evaluating the area it was concluded that all emergency exits where indeed properly signaled and lit, also all areas where fire extinguishers were located were too properly sign. The following are some of the signs that could be found within the area in question:

Figure 35. Emergency Signs

It can be concluded that the area in question did count with the minimum safety standards required for operations based on the NRD-2. Nonetheless there were several mistakes that took place that day that gave way to the occurrence of such fire. According to the fire departments situational analysis, electrical equipment and extensions were used which didn't meet the standards of safety and security, making it easier for an electrical accident and a subsequent fire to happen. Also, safe-work procedures were not followed, no risk assessment was previously elaborated and there was no industrial safety supervision as well as no electrical supervision.

12 CONCLUSIONS AND RECOMMENDATIONS

By means of this thesis a framework into building codes and safety aspects for public buildings in Guatemala was studied. Guatemala like many third world countries is in grave need of standardized civil engineering rules. Rules or norms that specify the way constructions are to take place, from the materials used, the construction methods up to the safety aspects. This research then focused on those safety aspects in order to guarantee the well being of the users. This thesis based its research on the recently developed Second Disaster Reduction Norm (NRD-2): Minimum Safety Aspects for Public Buildings in Guatemala.

The objective of having a norm that stipulates the safety measures for public buildings is to care and save human life, as stated in the Constitution of the Republic of Guatemala. By setting minimum standards in construction it also ensures the conditions for the development of the productive and creative activity of Guatemalan society. Added to that AGIES together with CONRED seek where possible to foresee the consequences arising from natural or man made disasters in the country.

It is necessary to establish this norm because Guatemala is a land characterized by its constant seismic activity, which has identifies that the materials and techniques used in the construction of buildings do not take into account both safety standards in construction and renovation projects. Therefore, it is necessary to establish minimum standards to prevent damage in both buildings as the people who make use of them.

AGIES is the Guatemalan Association of Structural and Seismical Engineering, composed of competent professionals in that field. It was them who posed the first proposal for setting Disaster Reduction Standards and it is they who are responsible for performing the review and updates of the norms every so often. Through the standards, AGIES collaborated with the national Government and particularly with CONRED as for it to count with the minimum requirements in terms of structural and seismical guidelines. Also, CONRED being integrated by representatives of government institutions, the private and public sector, it to revises, validates and gives legal life to all Disaster Reduction Norms.

In order to understand the importance of the NRD-2 all elements and safety criteria have been mentioned and thoroughly explained in this thesis project. The relevance of this norm has been proven by means of stating the different natural hazards of cyclical recurrence Guatemala phases each year. Scenarios were then created to better represent the possible outcomes that these hazards can have over the people's safety and the importance of having contingency plans in place based on norms such as the NRD-2 in order to guarantee the safety of the people.

The use of the NRD-2 was then graphically shown by means of examples where all the different safety aspects of this norm were evaluated. The same evaluation procedure took place when analyzing a real disaster, that of a fire in an Expo Center in Guatemala. The analysis of the building showed that in fact all safety aspects required by the NRD-2 had been followed. The emergency exits were fully accessible, well illuminated and properly signed as well as other emergency response factors such as the strategic placement and signaling of fire extinguishers. Everyone who was inside at the time of the fire was promptly evacuated, the fire was controlled an no human casualties had to be reported.

In order to evaluate new and existing buildings for the application of safety elements defined by in the NRD-2, an evaluation format was created. This format takes into consideration all safety aspects a building should have in order to comply with the norm. All buildings must be evaluated and changes made to those that do not comply with what is stated. These process even though a very important one requires of a lot of time and manpower. Therefore the mass evaluation process was not the subject of this thesis and is left open for future researchers to consider.

Finally a very important element of study of this thesis was the evacuation risk analysis made for an auditorium but which can be used for any other type of building. More specifically this evacuation analysis was done taking into consideration the situation that would rise in a building were there is a fire. Different variables such as the number of exits and obstruction levels as well as the survival threshold of a human being in a situation of smoke were evaluated and its effects on the evacuation time. This model, depending on the variables selected gives a final assessment on the amount of casualties an emergency situation could derive which can help in the preparation of emergency evacuation systems. The implementation of Fire Risk Analysis is very important since as it was explained before, there is a great gap in the fire engineering field compare to other fields with regards to the determination of acceptable variables. The existence of norms and codes help in making buildings safe for the public but that does not mean that there is still a longs way to go before fires risk engineering can become a full science.

The safety and well being of the public is something that has to be on the list of priorities of every civil engineer, architect and contractor. It is by the existence of rules such as the Second Disaster Reduction Norm that authorities are able to guarantee this safety to the general public. The work entities such as AGIES and CONRED are doing is the kind of work that deserves to be recognized since it is because of them that citizens can go about their daily routines without giving safety a second thought.

APPENDIX A

NATIONAL COORDINATOR FOR DISASTER REDUCTION
AGREEMENT NUMBER __________-2011

Guatemala, 2011

THE NATIONAL COUNSIL FOR DISASTER REDUCTION

WHEREAS:

It is the duty of the State to protect human life, ensuring the people of the country the conditions for the development of the productive and creative activity and foresee possible consequences that may result from natural or man-made disasters;

WHEREAS:

That in case of accidents, buildings and facilities within which come to focus groups of people should have the elements and procedures that facilitate the effective protection of the physical integrity of its occupants, so it is necessary to establish rules that encourage disaster reduction in this regard;

WHEREAS:

That the Executive Secretariat of the National Coordinator for Disaster Reduction has developed the Integrated Operational Procedures instrument called Emergency Response, which contains procedures and tools whose implementation prevents the physical integrity of the people who are in buildings and facilities of public use, making its standardization and adoption of general relevance.

THEREFORE

In the exercise of its functions under article 3, paragraph a) of the Law of the National Coordinator for Disaster Reduction of Natural or Man-made Origin and article 6, sections o) and p), of the Rules of the National Coordinator for Disaster Reduction of Natural or Man-made Origin.

AGREES ON

Issuing the following:

DISASTER REDUCTION RULE NUMBER TWO (NRD-2),
Minimum Safety Measures for Public Buildings

Article 1. Objective. This agreement aims to establish the minimum technical standards and safety criteria to be observed in buildings and facilities of public use and to protect the people in case of natural or man-made events that could jeopardize their safety. The Minimum Safety Measures are a set of standards and actions contained in this Norm to be implemented in buildings and facilities of public use to achieve the described objective.

Article 2. Responsible Authorities. To fulfill the objective of this norm and to implement the Minimum Safety Standards and Emergency Planning, it establishes as responsible the lead institutions of each sector or activity, by means of what is stated in Article 4 of the Legislative Decree 109-96, and is shown in Appendix 1.

In case of multi-organizational events, the responsibility will be shared between the institution in charge of the location where the event is taken place and the institution in charge of the development and realization of the event.

The actions and omissions that constitute any infraction or breach of this norm will be sanctioned in accordance with the established article 20 of the 109-96 decree, without any prejudice that if the action or omission constitutes a felony or fault, the conducive will be certified towards the competent court.

Article 3. Buildings and Facilities Included. This agreement applies to all buildings and facilities of public use that currently function as such, as well as those that will be developed in the future. Are considered buildings of public use, regardless of the property holder to which access is allowed, with or without restriction of staff (employees, contractors and subcontractors, among others) and/or users (as clients, customers, beneficiaries, stakeholders, etc).

The following are considered buildings of public use:

h) Buildings that are located on public or private offices;
i) Buildings for the establishment of shops, including markets, supermarkets, wholesales, outlets, malls and the like.
j) Buildigs devoted to making all kinds of events;
k) Schools, public and private, including primaries, high-schools, collages, universities and their extensions, or training centers, and the like.
l) Health Centers, hospitals, clinics, nursing homes, whether public or private;
m) Recreational centers, amusement parks, including outdoor playgrounds, cinemas, theaters, churches, clubs and the like.
n) Other buildings

Article 3. Responsible. For purposes of this regulation, those subject as responsible are the owners of each property including buildings and facilities. If the property in question is being used legitimately by someone other than the owner, both of which are jointly responsible for compliance with these regulations.

Article 4. Emergency Response Procedures in new buildings. Who ever is responsible for the construction or installation of new public use buildings should develop a procedure for responding to emergencies, which should be called Project Emergency Response Procedure and should contain the same minimum safety standards approved by this agreement. Those responsible for the building or facility in question must submit to their knowledge and assessment the draft for Emergency Response Procedures, to the competent authority prior to the start of works.

The competent authority should evaluate the projects and if it considers them adjusted to this regulation, shall, within thirty days approve of them. Managers should implement the measures contained in the relevant Plan, within the stipulated thirty days, having to prove in a document its implementation to the competent authority.

Article 5. Emergency Response Procedures in developing buildings. Developing buildings are considered those that at the time this agreements term has begum they have already began their formal construction activities and have not yet been finished. The responsible for these facilities should present the projects Emergency Response Procedure Plan to which Article 4 refers to within the agreed thirty calendar days after the beginning of this agreements term and in any event, before the end of the works in question.

Not even the competent authority with regards to the normative can neither accept nor validate the public opening of set public buildings without them counting with the Emergency Response Procedure Plan dully authorized.

Article 6. Emergency Response Procedures in existing buildings. The responsible for the buildings that fall under this normative that already exist with the normative passing must implement an Emergency Response Procedures Plan, dully approved by the competent authority. Those responsible must present an Emergency Response Procedures Plan before the competent authority within twelve months of this normative passing, meeting the requirements of Article 5, and have twelve months to realize the required physical modifications as stipulated by the plan.

Article 7. Emergency Response Procedure Registry. The competent authorities must meet in a chronological matter the Procedures that it authorizes, leaving proof of it on a Emergency Response Procedure Registry and having to emit monthly reports of the authorized plans to the Executive Secretariat for Disaster Reduction.

Article 8. Definitions. For purposes of this normative, the technical terms are defined as followed:

External Balconies: An area or space that projects from a wall out a building that is used as an emergency exit. Its long side must be open in at least 50% of its length, and the open space above the rail must be built in a way so it prevents the accumulation of smoke and toxic gases.

Exit Alley: It is a roofed exit that connects an exit to an emergency exit patio with public movement.

Occupancy Loads: It refers to the capacity of an area to harbor within its physical limits a set number of people.

Emergency Fittings: It is the conglomeration of pieces that together form a mechanism of quick release. The activation piece should extend across the width of the door and shall extend at least half the width of the doors leaf on which it is installed.

Emergency Exit Patio: It is a patio or yard that has access to a public road for one or more of the required exits.

Emergency Exit: It is a continuous mean without obstruction of exits to a public road and it includes all the necessary elements such as hallways, alleys, doors, gates, exterior balconies, ramps, escalators, stairs, smoke enclosures, horizontal exits, emergency exit patios and yards.

Horizontal Emergency Exits: It is a buildings exit to another building in approximately the same level, or around a wall build as it should for the separation and occupation of two hours and which completely divides a level in two or more separate areas that make up a fire shelter that provides smoke and fire protection.

Public Emergency Road: It refers to any road, alley or similar piece of terrain without obstructions from the ground to the sky that is available in a permanent matter for public use and which has a free width of at least 3 meters.

Article 10. Determining the Occupancy Load. To determine the occupancy load it must be assumed that all parts of the building are fully occupied at the same time. The occupancy load will them be determined as follows:

a) For areas that do not hold fixed seats, the occupancy load can't be less that the floor area (square meters) divided by the factor indicated in table 1. When the structures use/type is not specified in table 1, it must be calculated using the type that seems most likely to its real use. For buildings or part of buildings with multiple uses, the occupancy load must be calculated with the one that results from the larger number of people.
b) For areas with fixed seats, the number of fixed seats will determine the occupancy load. The required corridors length between seats cannot be used for any other purpose. For areas that hold fixed benches, the occupancy load must be less than one person for every 45 centimeters of bench. When there are cabins in food areas, the occupancy load must be one person for every 60 centimeters of cabin.

Article 11. Maximum occupancy load. The maximum occupancy load will not exceed the emergency exits capacity in accordance with the stipulated by this norm. The breach of this article will lead to the closure and immediate evacuation of the area that has exceeded its maximum occupancy load. The closure and immediate evacuation which are referred to in this article can be organized by the competent authority, general services chief or fire commander, the sheriff, chief of district police, chief of the National Civilian Police, or Executive Secretary, Deputy Executive Director, Regional Officer, Departmental Delegate, Deputy or Assistant, Tactical strategic, National Coordinator for Disaster Reduction – CONRED.

Article 12. Maximum Occupancy Signs. Any area that has an occupancy load of 50 or more people, without including areas with fixed seats, and which is used to hold meetings, lectures, restaurants or similar uses must have a sign that indicates the maximum capacity of that area and shall be placed in a visible place near a main exit. These signs must be kept in good legible conditions. The Executive Secretariat of the National Coordinator for Disaster Reduction – CONRED must approve its design.

Article 13. Required number of emergency exits. Every building or its utilized part must count with at least one emergency exit. No less than two when it is required by table 1 and additional exits when:

a) Each level or its part with an occupancy load of 501 – 1,000 people must have no less than three emergency exits.
b) Each lever or its part with an occupancy load larger than 1,000 people must have at least four emergency exits.
c) The number of emergency exits required by any level must be determined by means of its own occupancy load plus the following percentages of the occupancy loads of other levels which connect to the level in question:
    a. Fifty percent of the next upper levels occupancy load and 50 (fifty) percent of the next lower levels occupancy load.
    b. Twenty five percent of the occupancy load of the upper level to the next upper level of the level in consideration.
d) The maximum number of required emergency exits for any level must be maintained until reaching the buildings main exit.

Article 14. Emergency Exit Width. The total emergency exit width in centimeters, will not be less than the occupancy load multiplied by 0.76 for stairs and 0.50 for other types of emergency exits, nor will it be less than 90 centimeters. The total width for emergency exits must be equally divided between all emergency exits and the maximum width of required emergency exits of any level must be kept throughout the entire building.

Article 15. Emergency Exits location. In the case where the requirement is met by two emergency exits, these must be located with a separation measured in a straight line between them of no less than half the distance of the largest diagonal of the building or area to be evacuated.

When three or more exits are required, at least two of them bust be located with a separation measured by a straight line between them of no less than half the distance of the largest diagonal of the building or area to be evacuated. The additional exit(s) must have an addecuate separation between them, so than if one of them is blocked the others remain available for evacuation.

Article 16. Distance to the emergency exits. The maximum distance to travel from any point within the building to an emergency exit in a building not equipped by sprinklers must be of 45 meters or 60 meters when it does count with sprinklers.

In single floor buildings that are being used as warehouses, factories, hangars that do count with sprinklers and smoke ventilation systems, the maximum distance to an emergency exit can be increased to a maximum of 120 meters.

Article 17. Exiting by means of other areas. Other rooms can have one emergency exit that goes through an adjacent room, provided there is a way out that is clear, direct and unobstructed.

Article 18. Doors. All emergency exit doors must be of pivot or hinge and must open in the direction of the exit. The fitting of the door must open when a force of 6.8 kilograms of force is applied and the door shall become subject to movement with the application of 13.6 kilograms-force. All forces must be applied on the side of the door where the hardware and handles are installed. The door must have emergency hardware.

Doors that open on both directions may not be used when:

a) The occupancy load is 100 or more.
b) The door is part of a fire protection system.
c) The door is part of a smoke control system.

When using doors that open in both directions, they should have a window measuring no less than 1290 square centimeters.

Doors must be able to be opened from the inside without requiring any type of key or special knowledge or effort.

It is explicitly prohibited the use of hand pins mounted on the surface of the door. The release of any door leaf should not require more than one operation.

The minimum dimensions for doors used as emergency exits must be of 90 centimeters wide and 203 centimeters high.

Sliding and rotating doors cannot be used as emergency exits.

The emergency exit doors must be labeled in accordance with the terms specified in this statement.

Article 19. Floor level in doors. Regardless of the occupancy load, there must be ground or rest on both sides of the door used as and emergency exit. The floor or rest may not be more than 12 millimeters below the doors frame. The rest must be perfectly horizontal with the exception of breaks located outside which may have a maximum gradient of 21 millimeters per meter.

Article 20. Door rests. All rests must have a width of no less than the stairs or doors width, whichever is greater. The rests must have a length of no less than one hundred and ten centimeters. When the rests serve an occupancy load of 50 (fifty) or more, the doors in any position must not reduce the required rest dimensions to less than half its width.

Article 21. Additional doors. When there are additional doors for exit purposes, they too must abide by what this norm states.

Article 22. Hallways. The minimum width for hallways used as evacuation routes must be as stated in article 14 but must not be less than 90 centimeters for occupancy loads bellow 50 and 110 centimeters for occupancy loads of 50 or more. The minimum height will be of 210 centimeters and there can't be any obstruction that might reduce the hallways width.

Article 23. Stairs. Any two or more risers shall comply with the provisions of this rule. The minimum width of the steps used in escape routes shall be as specified in Article 14 but not less than 90 centimeters for occupancy loads bellow 50 or 110 centimeters for occupancy loads of 50 or more.

The riser of each step must not me smaller than 10 centimeters nor larger than 18 centimeters. The footprint of each step must not be less than 28 centimeters measured horizontally between the vertical planes of the adjacent footprint projections. All steps must have footprints and risers of equal lengths.

The stair rests must have a length, measured in the travel direction no less than its width or 110 centimeters. The maximum vertical distance between rests must be of 370 centimeters. For rests with doors, article 20 should be applied.

The stairs must have handrails on both sides and on each step with a width of more than 225 centimeters and should have at least one intermediate handrail for every 225 centimeters of width. The intermediate rail shall be located at distances approximately equal to the width of the stands. The top of the railings will be located at a height not less than 85 centimeter nor more than 97 centimeters from the top of the footprint. Handrails shall be continuous throughout the stairs. The pass should extend at least 30 centimeters at each end of the stairs and the end of handrails must be curved or post mounted. The width for the hands of the handrails sall not be smaller than 3.8 centimeters or larger than 5 centimeters and must have a smooth finish without sharp corners. The handrails that project from walls should have a clear space of no less than 3.8 centimeters between the wall and handrail.

When the stairs do not count with walls on both sides, the handrails must have a height of no less than 106 centimeters. Open handrails must count with intermediate rails or a decorative pattern so that the passing of a 10 centimeters in diameter sphere is prevented.

Exterior stairs of four or more level buildings must count with some kind of mechanism so that in case of an emergency fireman can come inn.

For buildings with four or more levels, at least one stair way must extend to the surface of the roof, except when the roof has a slope of 33 percent or more.

All stairs must be covered by an anti-slip surface and outdoor stairs must be made out of metal and be perforated in order to prevent them from corrosion and water formations.

Article 24. Emergency Ramps. All emergency ramps must comply with the requirements of this norm.

The minimum width for ramps used in escape routs shall be as indicated by article 14 but no less than 90 centimeters for occupancy loads smaller than 50 and 110 centimeters for occupancy loads of 50 or more.

The maximum slope for emergency ramps must be of 8.33 percent when used by people in wheelchairs or 12.5 percent when not used by people in wheelchairs.

The ramps must have rests in the upper and lower parts and at least one intermediate rest for every 150 centimeters of elevation. Upper and intermediate rests must have a length of no less than 150 centimeters. Lower rests must have a length of no less than 183 centimeters.

The doors located on either side of the ramp must not reduce the minimum rest dimensions to less than 106 centimeters.

All ramps must have handrails in accordance with the specified stair requirements.

The surface of the ramps must be slip resistant.

Article 25. Aisles. The clear widths of aisles in auditoriums, theaters, classrooms and other rooms with fixed seating will depend on the occupancy load of the fixed seated part that uses the corridor under consideration.

The clear width of the aisle expressed in centimeters must not be less than the occupancy load of that aisle multiplied by 0.76 for isles with slopes larger than 12.5 percent or multiplied by 0.51 for isles with slopes smaller than 12.5 percent.

When two isles converge into one, the minimum width must not be less than the sum of the two original widths.

When fixed seats are arranged in rows, the width of the isles shall not be less than indicated above nor less than:

122 centimeters for isles with stairs and seats on both sides.
90 centimeters for isles with stairs and seats on one side.
58 centimeters between the handrails and seats when the aisle is subdivided by handrails.
106 centimeters for flat aisles or with ramps and seats on both sides.
90 centimeters for flat aisles or with ramps and seats on one side.

Aisle ramps must not have a slope larger than 12.5 percent.

Article 26. Fixed seats. The following requirements apply to areas with fixed seats.

The minimum free space between seat rows must be:

30 centimeters for rows of 14 or less seats.
30 centimeters plus 0.76 centimeters for each additional seat after 14 to a maximum of 56 centimeters.

The space between rows of seats is the horizontal clearance between the seat back of the front row and the nearest projection of the row. When the seats are automatic, the distance can be measured with the seats up. When the seats are not automatic, the clearance should be measured with the seats down.

Article 27. Emergency Exit Lighting. All emergency exits, including aisles and hallways, ramps and stairs must be illuminated all the time the building is being used. The minimum intensity for the lighting, measured at floor level must be of 10.76 lux.

For buildings with an occupancy load of 100 or more, the emergency lights must have an alternative power source that automatically activates in case the main power source fails. The alternate source can be a battery bank or an emergency generator.

SIGNALING

Article 28. Emergency Exit Signs. It is compulsory to label the exits when there are two or more emergency exits. This labeling must have an internal or external lighting by a minimum of two lamps or bulbs or be of a selfluminescent type. The signs should be illuminated with a minimum intensity of a 53.82 lux per bulb. The energy of one bulb will come from the principal energy source and the energy from the other bulb will come from batteries or an emergency generator.

The signs that are located on the wall shall be constructed of metal or other approved material that is noncombustible and the sign attached to the outer wall of concrete, masonry or stone, must be safely and securely connected by means of a metal anchor, expansion bolts or screws. Walls made out of wood, gypsum board or fibrocement are not fit to mount emergency information signs.

Signs that are mounted on walls must be properly attached, according to the provisions stated on Table 2, in accordance with CONRED's Signaling Manual for Buildings of Public and Private Use. It is not allowed to install signs on the ceilings or hang them from there. The installations of portable signs are accepted if they will remain on temporarily and they cannot be fixed to the floor by means of permanent anchors.

1) **Maximum Lift Capacity Sign.** Informative sign, indicating the elevator's maximum capacity in number of people. Installation: in a visible location such as gateways and the interior of elevators. Applicable to all types of buildings that have this type of vertical transportation method.

2) **Emergency Exit Sign.** Informative sign, which is used to indicate all possible exits in case of an emergency, installed in visible locations such as on top or immediately adjacent to an exit door leading to a safety zone. This signal works in close relation with the following signs: right escape route, left escape route, upward escape route and downward escape outlet.

3) **Right Escape Route Sign**. Informative sign with a directional arrow, in this case indicating an escape route or escape to the right. Installation: on walls of buildings of public or private use. This sign works closely with the "Emergency Exit" sign as it is intended to guide the evacuation to the right, bearing in mind that once the right direction has ended, and escape route will be found.

4) **Left Escape Route sign.** Informative sign with a directional arrow, in this case indicating an escape route or escape to the left. Installation: on walls of buildings of public or private use. This sign works closely with the "Emergency Exit" sign as it is intended to guide the evacuation to the left, bearing in mind that once the left direction has ended, and escape route will be found.

5) **Upward Escape Route Sign.** Informative sign indicating an upward escape route leading to an exit in case of an emergency. Installation. On walls or immediately adjacent to stairs leading up. The sign will be

installed in all types of buildings and is closely related to the Emergency Exit signs.

6) **Downward Escape Route Sign.** Informative sign indicating a downward escape route leading to an exit in case of an emergency. Installation. On walls or immediately adjacent to stairs leading down. The sign will be installed in all types of buildings and is closely related to the Emergency Exit signs.

7) **Safety Zone Sign.** Internal or external environment of a building, whose construction, design and/or location is free from threats or has a low probability of risks that pose a threat to human life or their property. Within safe zones one or more points of reunion converge in order to protect human lives. **Installation:** In visible places such as patios, parking lots or any area that does not pose imminent danger of falling glass or other items in case of earthquake or fire. The use of such sign shall be in both public and private buildings.

8) **Meeting Area.** External location of a property, identified to meet the vacating staff in a preventive and orderly manner, following an evacuation. **Installation:** In visible places such as patios, parking lots or any area that poses no risk.

9) **Dirty or Contaminated Area Sign.** Informative sign indicating the existence of a dirty or contaminated area. **Installation:** In visible places such as: laboratory samples, hospitals, chemicals, food, bottling and garbage collection facilities, etc. The sign must be installed directly on walls or other structures.

10) **Pollutant Free Area Sign.** Informative sign indicating the existence of pollution free and clean area. **Installation:** In visible places such as sample laboratories, hospitals, chemical factories and so on. This sign will be installed directly on walls or other structures, clearly indicating to workers the existence of these pollutant free areas.

11) **"Care when going down" Signs.** Informative sign, which indicates the existence of a change in slope/height and for such reason the areas where this sign is placed, should be traveled with care. **Installation:** In visible places such as stairs, uneven floors, etc. This sign must be installed in public and private buildings.

12) **"Push to Open" Sign.** Informative sign that indicates to what side the door opens to. **Installation:** In Visible places such as doors that open on one or both sides, double doors, etc. the sign must be placed directly above the door with the objective of homogenizing all exit door signs. This signal is directly related with the "Pull to Open" sign since they will be installed in pairs, one on the outer part of the door and one on the inner part with regards to its orientation.

13) **“Pull to Open” Sign.** Informative sign that indicates to what side the door opens to. **Installation:** In visible places such as doors that open on one or both sides, double doors, etc. the sign must be placed directly above the door with the objective or homogenizing all exit door signs. This signal is directly related with the “Push to Open” sign since they will be installed in pairs, one on each side of the door with regards to its orientation.

14) **“Break in case of an emergency” Sign.** Informative sign that indicated to break in order to gain access and it’s necessary to consider it: where a glass panel must be broken to gain access to a key or other means. Where it is necessary to break a panel that holds fire fighting equipment or to create an evacuation route. **Installation:** Directly on glass panel.

15) **“Don’t run on stairs” Sign.** Used to indicate that it is forbidden to run up or down the stairs in case of an emergency, whether they are principal or emergency stairs. **Installation:** In a visible areas of public and private buildings (main or secondary stair cases of hospitals, libraries, etc.). The installation of this sign must be done on the beginning and end sides of the staircase.

16) **“Do Not Use Elevator in Case of Loss of Fire or Power Outage” Sign.** Used to indicate the prohibition to use elevators in case of fire, earthquake or power outage, forcing thus the use of main or emergency stairs. **Installation:** In visible places within private or public buildings such as hospitals, libraries, etc. that have this type of equipment (elevators). The sign must be located immediately adjacent to the elevators calling buttons.

17) **“No running in the hallway” Sign.** Used to indicate the prohibition of running in both directions of a hallway for workers and the general public to apply in everyday situations as well as emergencies. **Installation:** On visible within public or private buildings (hospital corridors, libraries or any other building). The sign must be installed on walls or other structures so that they can clearly warn.

18) **“Only Authorized Personnel” Sign.** Used to indicate the prohibition of entry to places to outsiders or those who don’t count with the authorized preparation, clearance or protection equipment necessary to access. **Installation:** On visible places within private and public buildings such as recovery and isolation rooms, warehouses, machines, power stations and substations, etc. Hospital, libraries and other buildings. The sign must be installed on the main access to the restricted area or adjacent access that lead to this area.

19) **“Do Not Block” Sign.** Sign indicating the prohibition in areas where an obstruction would present a particular hazard (evacuation routes, access to fire fighting equipment, etc.) **Installation:** Visible places within private and public buildings. The sign must be installed directly or

adjacent to doors or other similar places, so that it warns the staff and general public to not block those areas.

20) **"Dead End" Sign.** Used to indicate the prohibition of entry in case of an emergency, and it is not an escape route since it doesn't lead to a safe zone. **Installation:** On visible places within private or public buildings. The sign must be installed directly or adjacent to doors or other similar means, in such way that it warns the staff and general public that the route does not constitute and emergency exit.

21) **"Do not use water to put fire out" Sign.** Used to indicate the prohibition of using water as a means to extinguish a fire. **Installation:** On visible places within private and public buildings. The installation to fthis sign must be on walls or doors where it is indicated that the use of water to put out a fire poses great risk when used on electrically powered equipment or over substances in its three states (liquid, solid and gas) that when combined with water can have an aggressive reaction.

22) **Fire Extinguisher Location Sign.** Used to inform of the fire extinguishers location. This sign must be installed as many times as the number of extinguishers in the building. **Installation:** The sign must be installed on walls or other elements that hold the extinguisher.

23) **Wet Network / Fire Hose Sign.** Used to indicate the location of the output of the wet network provided with hose and nozzle. This sign will be installed, as many times as there are wet networks in the building. **Installation:** It must be placed in boxes containing only the means for fighting the fire. The sign will be installed directly above the box or wet pipe spool.

24) **Dry Network Sign.** Used to indicate exit mouth of a dry network. It must be installed as many times as there are dry networks. **Installation:** It must be placed immediately on top of the dry network exit.

25) **Emergency Phone Sign.** Used to indicate the location of a phone destined to permanently warn of emergency situations. The number of signs must match the number of emergency phones installed in the building. **Installation:** On visible areas, immediately or very near the phone on walls or other elements.

26) **Fire Alarm Sign.** It can be used alone or in conjunction with the sign (manual alarm activation), in case the manual activation command is connected to the fire alarm so that it is immediately obvious to all concerned. **Installation:** On visible places within all types of buildings. The installation of this sign is made directly on walls or other elements in such a way that is easily seen by all occupants.

27) **Joint Fire-Fighting Equipment Sign.** It must specify the location of a set of equipment against fire, installed as many times as there are sets

in the building. Note that this sign binds to other signs to avoid unnecessary proliferation of signs. Thus the sign will be installed only in niches where there are the following: fire extinguisher, telephone, wet network, etc. **Installation:** On visible places within private and public buildings. Applicable in case of the existence of such niches it will be directly installed on walls.

28) **Fire Cutting Door Sign.** Indicates the locations of a fire-cutting door, which must remain close at all, times or open when connected to a web of smoke sensors. It provides the assimilation of spaces and directs the fire to other areas. **Installation:** on visible places close to or over the fire-cutting door.

29) **Inert Electrical Network Sign.** Used to indicate the location of an inert electrical connection. The number of signs installed must match the number of inert connections within the building. These connections are to be used specifically by firemen. **Installation:** On visible areas within private and public buildings, usually it is located on the inferior floor surface. The installation of such sigh must be at a height no less than 1.60 Mt. immediately over the connection.

30) **Manual Alarm Activation Sign.** This sign must be used to indicate the location of the manual alarm activation. It is used for: a) Manual alarm activation, b) Manual command of fire protection system (such as, fixed fire extinguisher installation). **Installation:** Within private and public buildings. The installation of such sign must be done as close as possible to the manual activation and shall be installed as many times as there are manual activation systems.

31) **Signaling as stated by CONRED's Safety Manual.** CONRED's safety signaling manual indicates the specific shapes, official colors and signal location for private and public buildings within the national territory.

Article 29. Color Identification. The colors used in signage and marking of emergency exits will be identified according to the international system RBG 8 bits per channel for a total of 24 bits using hexadecimal notation. The identification scheme consists of 6 hexadecimal digits. From left to right, the first two digits represent the red channel, the next two digits represent the green channel and the last two digits represent the blue channel. The hexadecimal digits to be used are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

Article 30. Attention Colors. To indicate danger situations the following color will be used: FF0000 (red).

Article 31. Reforms. The document that supports this Second Disaster Reduction Norm – NRD 2, included in this agreement shall be reviewed and amended by the Executive Secretariat of the National Coordinator for Disaster Reduction, which proposed reform, taking duly justified and in any case to technical criteria, the National Council for Disaster Reduction.

Article 32. Validity. This agreement takes effect from the day following its publication in the Journal of Central America.

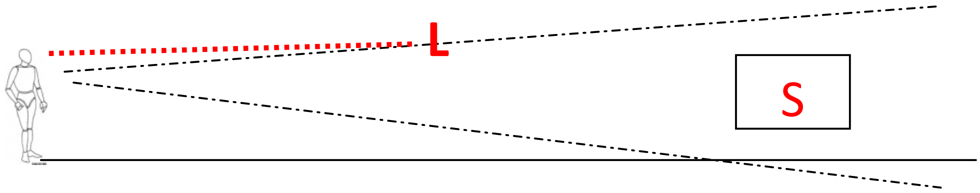
Article 33. Prohibition of alterations. It is prohibited to alter a building or structure so as to reduce the number of exits or reduce the capacity to less than indicated by this normative.

APPENDIX 1

TABLE 1. OCCUPANCY LOAD

Use	Minimum of two exits, without elevators, are required whn the number of occupants is at least:	Occupancy Load Factor (square meters)
Aviation Hangars (with no rapairs area)	10	45
Auction salons	30	0.65
Auditoriums, churches, chapels, dance floors, stadiums, bleachers	50	0.65
Meeting and conference rooms, diners, restaurants, bars, exhibition rooms, gyms, stages	50 D = 64 m	1.39
Orphanages and elderly homes	6	7.43
Waiting Areas	50	0.30
Classrooms	50	1.85
Court rooms	50	3.70
Dorms	10	4.5
Living dwellings	10	28
Exercising rooms	50	4.5
Parking lots	30	18.5
Hospitals, sanatoriums, health centers	10	7.43
Hotels and apartments	10	18.5
Commercial Kitchens	30	18.5
Reading rooms in libraries	50	4.5
Factories	30	18.5
Shopping malls	50	2.8
Nurseries	7	3.25
Offices	30	9.30
Workshops in schools and vocational areas	50	4.5
Skating rinks	50	4.5 on rink and 1.4 on all other areas
Storage rooms	30	27.88
Stores and showrooms	50	2.78
Pools	50	4.5 para la piscina y 1.4 en las otras áreas
Warehouses	30	45
Everything else	50	9.30

VISUALIZATION DISTANCE (L) (meters)	MINIMUM SURFACE [S ≥ L^2 / 2000] (cm^2)	MINIMUM DIMENSIONS WITH REGARDS TO THE GEOMETRIC SIGN SHAPE				
		SQUARE (per side) (cm)	CIRCLE (diameter) (cm)	TRIANGLE (per side) (cm)	RECTANGLE (base 1.5: height 1) (cm)	
					BASE	ALTURA
5	125,0	11,2	12,6	17,0	13,7	9,1
10	500,0	22,4	25,2	34,0	27,4	18,3
15	1 125,0	33,5	37,8	51,0	41,1	27,4
20	2 000,0	44,7	50,5	68,0	54,8	36,5
25	3 125,0	55,9	63,1	85,0	68,5	45,6
30	4 500,0	67,1	75,7	101,9	82,2	54,8
35	6 125,0	78,3	88,3	118,9	95,9	63,9
40	8 000,0	89,4	100,9	135,9	109,5	73,0
45	10 125,0	100,6	113,5	152,9	123,2	82,2
50	12 500,0	111,8	126,2	169,9	136,9	91,3



APPENDIX 2
Colors

INTERNATIONAL COLOR CODES

16 Standard Colors (4 bits)

BLACK	NAVY	BLUE	TEAL	AQUA	
SILVER	GRAY	YELLOW	GREEN	OLIVE	LIME
RED	MAROON	WHITE	FUCHSIA	PURPLE	

256 RGB colors (8 bits)

RED FF0000	FF3300	CC3300	FF9999	FFCCCC	990033	MAROON 990000
	FF3333	CC3333	FFCC99	CC0066	993300	
	FF0033	CC0033	FF9966	FF6699	660000	
	000000	CC0000	663333	990066	330000	

LIME 66FF00	33FF33	66FF66	OLIVE 66FF00	99FF99	CCFFCC	GREEN 00FF00
	00CC00	009900		006600	003300	
	00CC00	009900		006600	003300	
	009900	006600		66FF00	009900	

AQUA 00FFFF	00FFFF	3333FF	TEAL 006666	6666FF	9999FF	BLUE 0000FF
	33FFFF	66FFFF		99FFFF	CCFFFF	
	CCCCFF	0000CC		000099	000099	
	CCCCFF	000066		000033	000099	

00CCCC	009999	006666	003333

YELLOW	FFFF33	FFFF66	FFFF99	FFFFCC
	CCCC00	999900	666600	333300

FF3300	FF3333	FF3366	FF3399	FF33CC	FF33FF
FF6600	FF6633	FF6666	FF6699	FF66CC	FF66FF
FF9900	FF9933	FF9966	FF9999	FF99CC	FF99FF
FFCC00	FFCC33	FFCC66	FFCC99	FFCCCC	FFCCFF
FFFF00	FFFF33	FFFF66	FFFF99	FFFFCC	FFFFFF
CC0000	CC0033	CC0066	CC0099	CC00CC	CC00FF
CC3300	CC3333	CC3366	CC3399	CC33CC	CC33FF
CC6600	CC6633	CC6666	CC6699	CC66CC	CC66FF
CC9900	CC9933	CC9966	CC9999	CC99CC	CC99FF
CCCC00	CCCC33	CCCC66	CCCC99	CCCCCC	CCCCFF
CCFF00	CCFF33	CCFF66	CCFF99	CCFFCC	CCFFFF
990000	990033	990066	990099	9900CC	9900FF
993300	993333	993366	993399	9933CC	9933FF
996600	996633	996666	996699	9966CC	9966FF
999900	999933	999966	999999	9999CC	9999FF
99CC00	99CC33	99CC66	99CC99	99CCCC	99CCFF
99FF00	99FF33	99FF66	99FF99	99FFCC	99FFFF
666600	666633	666666	666699	6666CC	6666FF

669900	669933	669966	669999	6699CC	6699FF
66CC00	66CC33	66CC66	66CC99	66CCCC	66CCFF
66FF00	66FF33	66FF66	66FF99	66FFCC	66FFFF
336600	336633	336666	336699	3366CC	3366FF
339900	339933	339966	339999	3399CC	3399FF
006600	006633	006666	006699	0066CC	0066FF
009900	009933	009966	009999	0099CC	0099FF
33CC00	33CC33	33CC66	33CC99	33CCCC	33CCFF
00CC00	00CC33	00CC66	00CC99	00CCCC	00CCFF
33FF00	33FF33	33FF66	33FF99	33FFCC	33FFFF
00FF00	00FF33	00FF66	00FF99	00FFCC	00FFFF
663300	663333	663366	663399	6633CC	6633FF
660000	660033	660066	660099	6600CC	6600FF
333300	333333	333366	333399	3333CC	3333FF

SIGNIFICANCE OF THE COLORS USED ON SIGNS

Safety Colors

Safety colors allow establishing and identifying the action to develop.

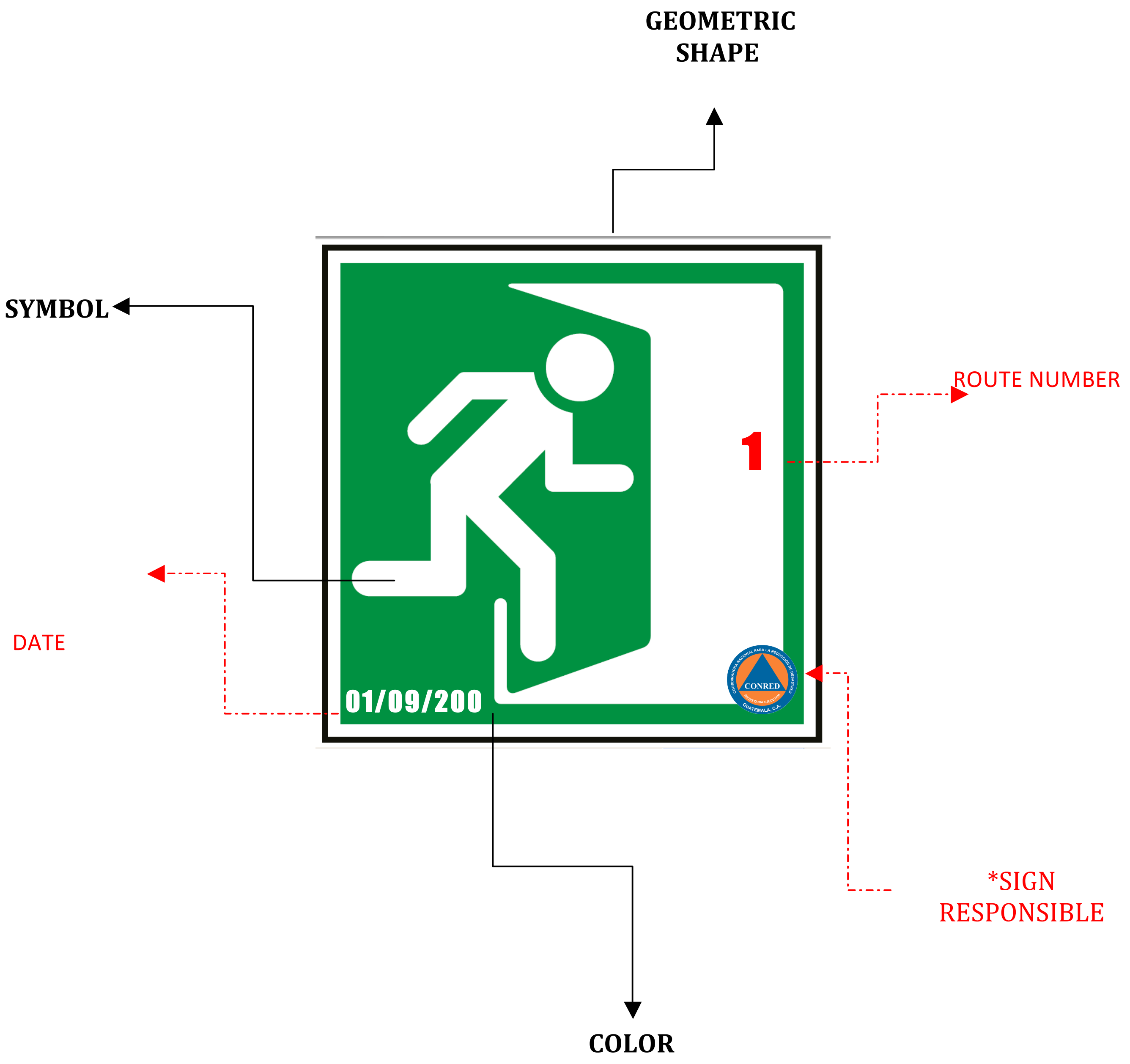
SAFETY COLOR	SIGNIFICANCE	INDICATIONS AND PRECITIONS
RED Cod. FFOOO	Stop	Stop some place
	Forbidden	Sign to forbid specific actions
	Material, equipment and systems to fight fire.	Location of fire fighting materials and equipment.
YELLOW Cod. FFFF33	Danger warning	Attention, precaution, verification and identification of dangerous situations.
	Area delimitation	Restricted área limits or of specific use.
	Danger warning due to ionized radiation	Sign to specify the presence of radioactive material.
GREEN Cod. 009900	Safe condition	Identification and signaling to indicate emergency exits, evacuation routs, safe zones, meeting points, emergency showers, eye washers, etc.
BLUE Cod. 000099	Obligation, information	Signaling for the realization of specific tasks. Provide information for all people.

Safety Colors

The color contrast will highlight the color characteristics of primary safety.

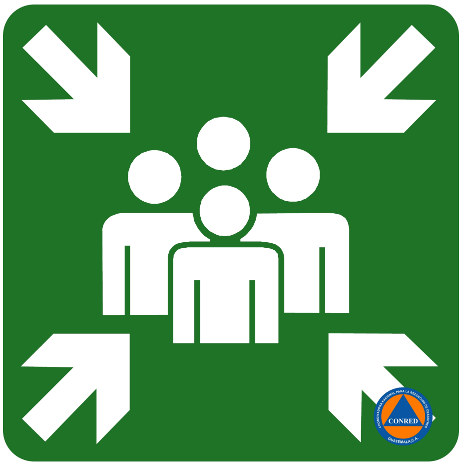
Color	Contrast
BLUE Cod. 000099	WHITE Cod. ffffff
GREEN Cod. 009900	WHITE Cod. ffffff
YELLOW Cod. FFFF33	BLACK Cod. 000000
RED Cod. FFOOO	WHITE Cod. ffffff

APPENDIX 3
Sign Components



LETTER TYPE: IMPACT
SQUARE SIGN WITH ROUNDED CORNERS
EXTERIOR FRAME IN WHITE 1.5 CM

Meeting Point Sign



Emergency Exit Sign

Fire Extinguisher Sign

Evacuation and Safety Signs

<table>
<tr><th>SIGN</th><th>MEANING</th></tr>
<tr><td></td><td rowspan="7">**EVACUATION ROUTE**</td></tr>
<tr><td></td></tr>
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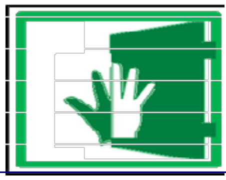
</table>

SIGN	MEANING
	EVACUATION ROUTE
	EMERGENCY SHOWER
	EMERGENCY EYE WASHER
	EMERGENCY EXIT
	

SIGN	MEANING
	MEETING POINT
	PUSH BAR TO EXIT
	PUSH TO EXIT
	EMERGENCY EVACUATION ROUTE FOR HANDICAPED PEOPLE
	
	
	

SIGN	MEANING
	
	**EVACUATION ROUTE FOR HANDICAPED PEOPLE**
	
	
	**EVACUATION ROUTE**
	
	

SEÑAL	SIGNIFICADO
	EVACUATION ROUTE
	
	FIRST AID
	EMERGENCY PHONE
	FIRST AID
	

APPENDIX B

RESPONSE PLANS FOR BUILDINGS OF PUBLIC USE

Business Name

Date of Update

Reff. #

General Information

Owners Name:		E-mail Address :		Phone #	
Tenats Name:		E-mail Address :		Phone #	
Contacts Name :		E-mail Address :		Phone #	
Elaboration Charge :		E-mail Address :		Phone #	
Elaboration Date :	dd_______ mm__________yyyy_______				
Building Name :					
Address :					

Signature and Stamp of Responsible | **Stamped Approval of Competent Authority**

Buildings and Facilities Included

Mark with an X

It's a Building : Under Construction ☐ New ☐ Existing ☐

Use of the Building :

Business Premises	☐	Health Center	☐
Market	☐	Hospital	☐
Supermarket	☐	Clinic	☐
Wholesale center	☐	Sanatorium	☐
Mall	☐	Church	☐
Educational Center	☐	Night Club	☐
Formation or capacitation center	☐	Other :	

Describe:

☐

Determintion of Occupancy Load

Indicate quantity

Total levels of the building ☐

Level ☐

Building with more than 4 levels

Marque con una x

	SI	NO
Fire department entry mechanism	☐	☐
It extends from the stairs until the roof	☐	☐
The roof has more than 33% incline	☐	☐

Type of Alternative Energy

Mark with an X

Emergency Generators ☐ Battery bank ☐

Threat Identification

Mark with an X

Internal Threats

Structural Conditions				Electrical equipment in poor condition					Location of gas instalations			
Wood in poor condition	Fractures Columns	Broken windows	Cracked walls and floors	Switches	Lamps	Control Telephone	Air Conditioning	Water Heater	Cilinders	Stationary Tanks	Oven Pilot	Gas Pipe

Hydraulics in poor condition				Sanitary in poor condition				Furniture in poor condition			
Water Pipes	Toilets	Water Tanks	Cisterns	Drainage	Sewers	Records	Drains	Chairs	Desks	Shelves	Records

Others :

External Threats

Mark with an X in the place for type of construction and indicate the quantity for building environment when needed

Construction Type								Building Environment							
Block		Gypsum Board		Partitions		Lamps		Contactos	Cable de alta tensión	Laderas < 25 mts. de distancia	Pared mal construidas o sin concluir	Arboles con mayor altura del edificio	Drenajes	Fabricas que utilicen materiales peligrosos	Gasolineras
Cracked		Cracked		Cracked		Poor Quality									
YES	NO	YES	NO	YES	NO	YES	NO								

Others :

NOTE : In poor condition and poor performance means poor location that may pose a danger to people.

Total Load Capacity per Area

Indicate the quantity when needed or just mark with an X.

Levels #

Area*

Number of fixed seats	Nimber of none fixed seats	Maximum capacity (quantity)	Signaling of Maximum Capacity (mark with an X)		Emergency Exits (indicate quantity)				Doors (indicate quantity)										
			YES	NO	Total width (cm)	Minimum distance between exits	Maximum distance between exits	Exiting by means of other rooms	With Hardware	Without Hardware	With Signs	Without Signs	With rests	Without Rests	< 90 cm in with	< 203 cm in hight	Rests longitude ˂ 110 cm	≥ 203 cm in height	Rests long > 110 cm

Corridors (quantity)				Stairs																
				With occupancy loads less than 50 (show quantity)				With occupacy loads higher that 50 (show quantity)				Antislipping surface (mark with an x)		Free height till roof (quantity)		Footprint (quantity)		Riser (quntity)		
< 90 cm wide	≥ 90 cm wide	< 210 cm high	≥ 210 cm high	< 90 cm wide	Rest: Long < its width or 110cm	≥ 90 cm wide	Rest: Long ≥ de its width or 110 cm	< 110 cm wide	Rest: Long < its weidth or 110 cm	≥ 110 cm wide	rest: Long ≥ its width or 110 cm	YES	NO	≥ 203 cm	> 203 cm	> 28 cm	< 28 cm	> 10 cm	> 18 cm	< 18 cm and >10 cm

Handrails

Indicate quantity

In stairs with widths > 225 cm				With width			With wall projection			Without a wall on one or both sides			Continuous	External		Internal Railing	
Intermediate	85 to 97 cm high	< 85 cm high	> 97 cm high	Of 3.8 cm to 5 cm	< 3.8 cm	> 5 cm	Of 3.8 cm	< 3.8 cm	>3.8 cm	106 cm high	< 106 cm hight	> 106 cm hight	Extended at 30 cm from the stairs	Smooth finish	sharp corners	Doesn't allow the pass of a sphere ≤ 10 cm	Allows sphere to pass ≤ 10 cm

General Observations

* Area: Indicate the number of rooms availabe at each level to assess

Emergency Ramps

Indicate quantities

Occupancy loads smaller than 50		Occupancy load larger than 50		Ramps slopes						Rests for inclines of 150 cm						Rests in doors adjecent to ramps	
				Wheelchair accesible			Not wheelchair accesible			Superior and immediate			Inferior				
< 90 cm wide	≥ 90 cm wide	< 90 cm wide	≥ 90 cm wide	8.33%	> 8.33%	≥ 8.33%	12.50%	> 12.5%	< 12.5%	150 cm of length	< 150 of length	>150 of length	183 cm of length	< 183 of length	>183 of length	< 106 cm	≥ 106 cm

Aisle width

Indicate quantities

With fixed seats			Convergence of two aisles	With stars and seats on both sides			With staris and seats on one side			Sub-divided with handrails			Flat or with ramp and seats on both sides			Flat or with ramp and seats on one side		
12.5 % incline	< 12.5 % incline	> 12.5 % incline		122 cm	< 122 cm	> 122 cm	90 cm	< 90 cm	> 90 cm	58 cm	< 58 cm	> 58 cm	106 cm	< 106 cm	> 106 cm	90 cm	< 90 cm	> 90 cm

Fixed seats						
Rows with 14 or less			For mor than 14 seats per row			
30 cm	˂ 30 cm	> 30 cm	30.76 cm	˂ 30.76 cm	56 cm	> 56 cm

Labeling of emergency exits and evacuation routes											
Illumination											
LUX	Emergency Exits			Total LUX per bulb (two bulbs nminimum)							
	Aisles	Ramps	Stairs	Exit signs				Evacuation route signs			
10.76					Bulb one	Bulb two	Automatic		Bulb one	Bulb two	Automatic
˂10.76				53.82				53.82			
>10.76				˂53.82				˂53.82			
				>53.82				>53.82			

Mark with an X

Sign location					Anchord		
Walls							
Concrete masonry	Rocks	Wood	gypsum board	Fibrocement	Bolt	Metal	Expansion screw

General Observations

Graphic identification of emergency exits

Alarm System

Mark with an X

Hearing				Visual		
Whistle	Auto parlantes	Siren	Bells	Emergency 'strob' lights	Rotating Emergency lights	Glowing signs

Other :

Communication system

Mark with an X

Hearing				
Cellphone	Radio	Beeper	Wireless Internet	Portable computer

Other :

Example

DIRECTORY

No.	Name	Responsibility within plan	Phone #	Radio Code	Beeper	e-mail
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

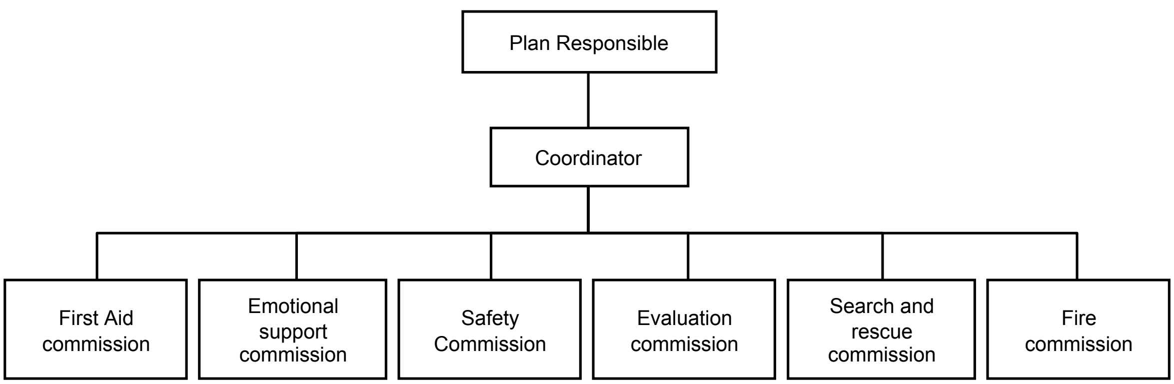
Resources to use in an emergency

Example

RESOURCES			
No.	Resource	Location	Quantity
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Organizational Structure

Make an organizational diagram placing the person in charge on each cell



Attention to the population (applies only to government entities)

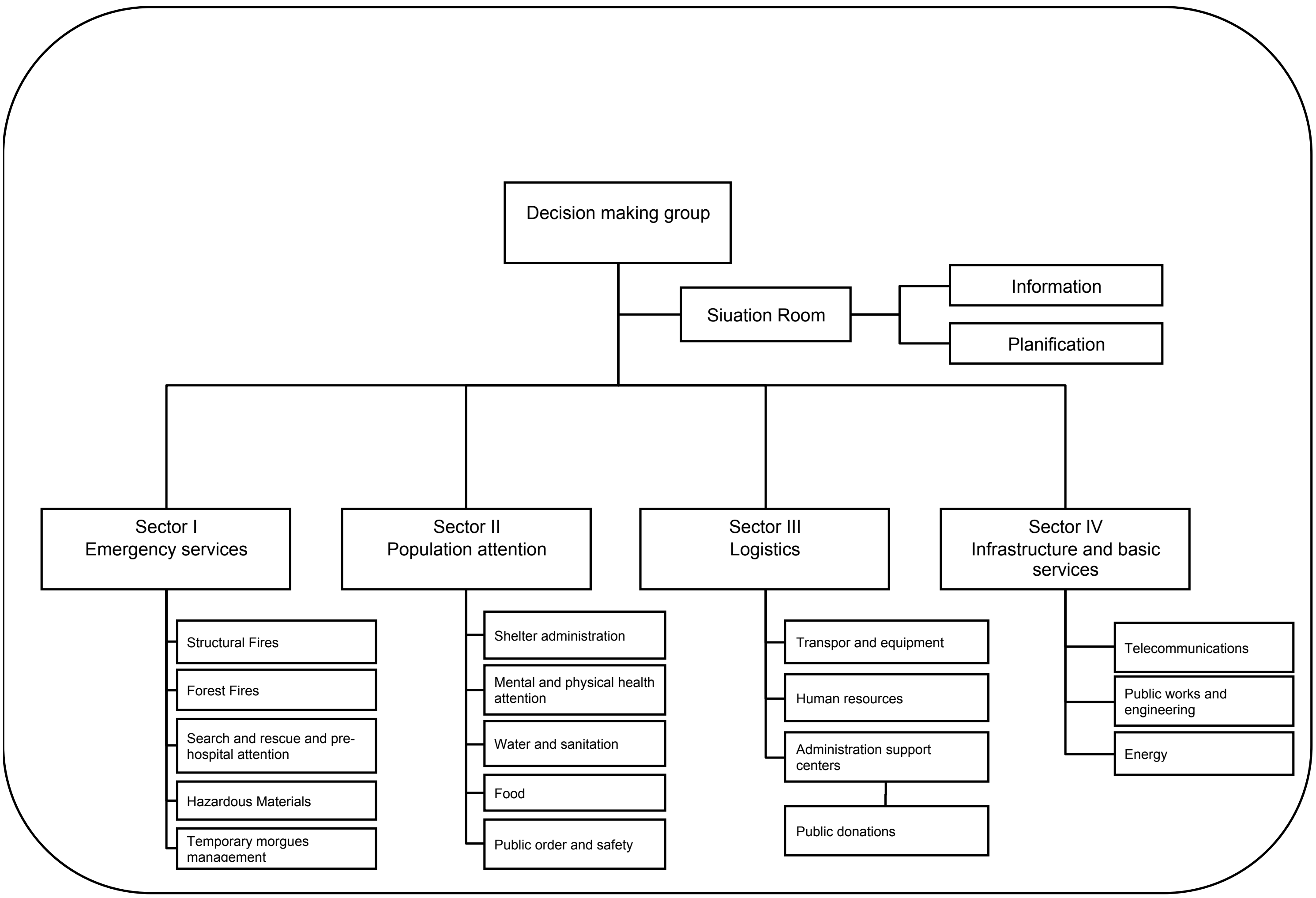
Integration to CONRED's system

Mark with an X

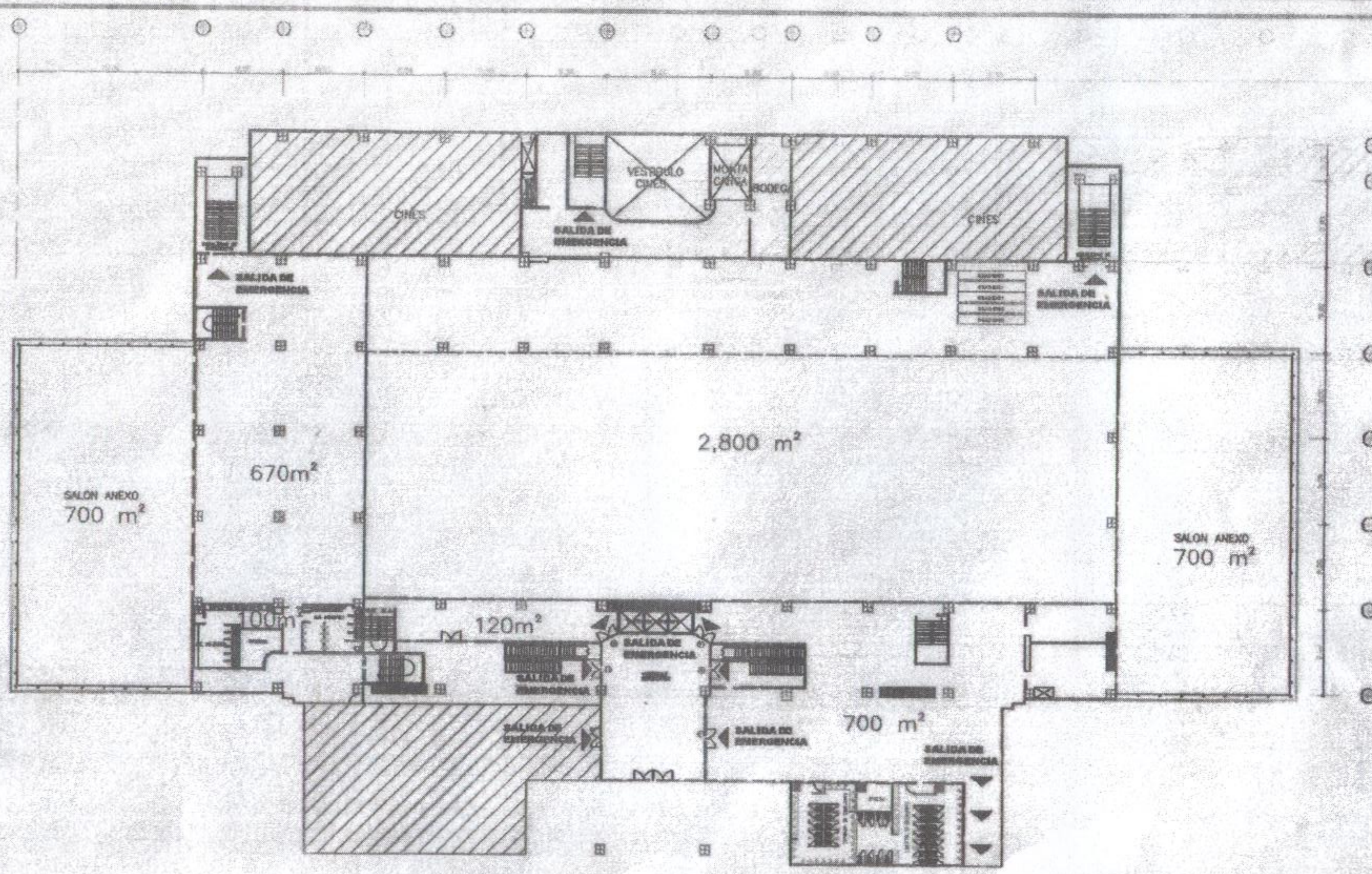
Officer active link to the SECONRED		Integrated workbench for PNR funcion		Areas for emergency care	
YES	NO	YES	NO	YES	NO

Organizational structure for population care

Make a chart placing in each box the person responsible



APPENDIX C

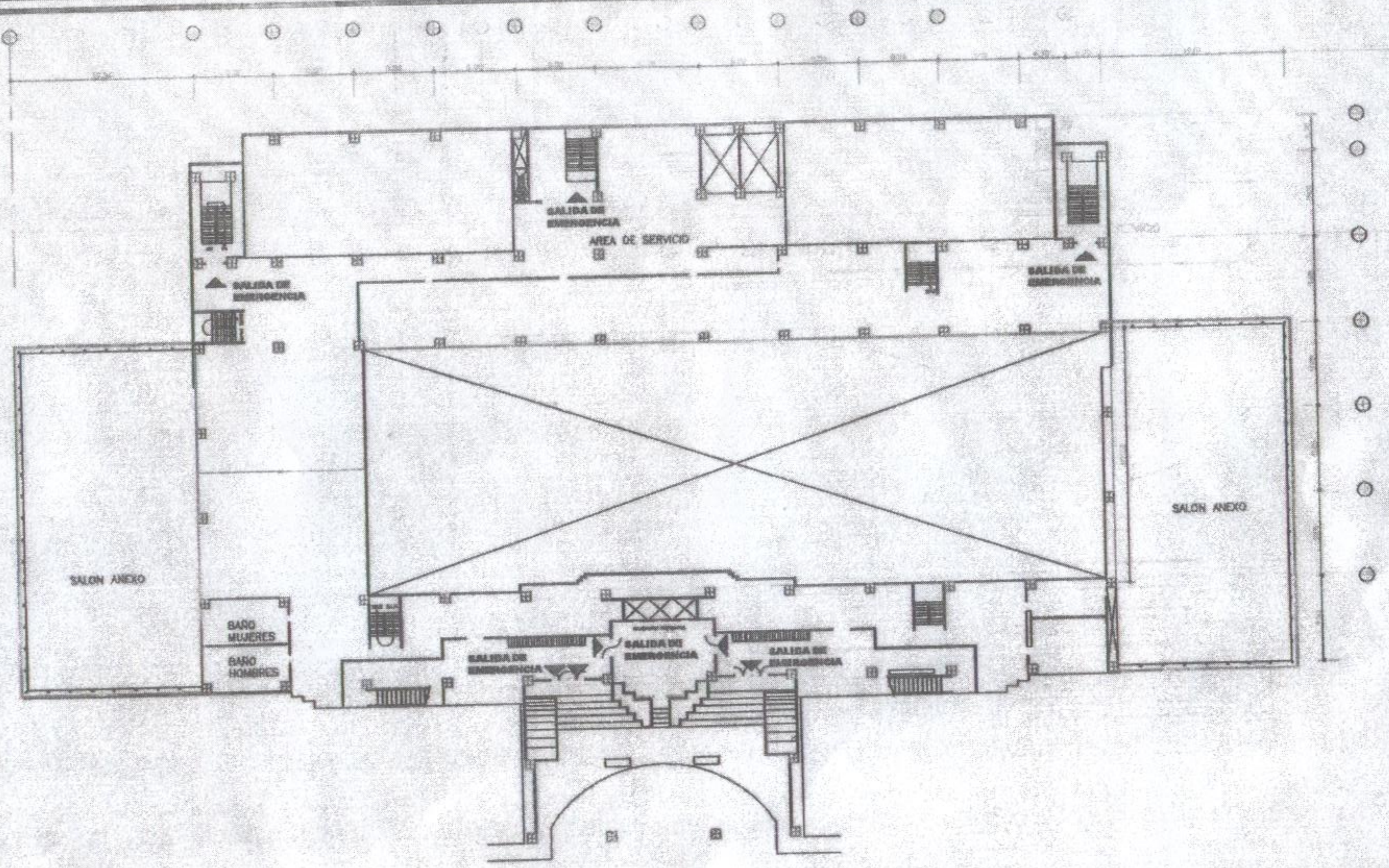


CENTRO DE CONVENCIONES
SALON LA PAZ EXPOCENTER NIVEL 2

ESCALA
1 : 200

PLANTA SALONES DE CONVENCIONES
SALON LA PAZ EXPOCENTER NIV.2

Hoja
00



SALIDA DE EMERGENCIA

Proyecto
Dibujo
Propietario

CENTRO DE CONVENCIONES
EXPOCENTER MEZZANINE NIVEL 3

Hoja 00

TIKAL FUTURA

APPENDIX D

FIRE RISK ASSESSMENT	
1. PREMISES PARTICULARS	
Premises Name:	**Use of Premises:**
Premises Address:	
Phone Number:	**Responsible person for Occupiers part of premises:**
Date of Risk Assessment	**Date of Review:**
Name and relevant details of the person who caried out the Fire Risk Assessm	
2. GENERAL STATEMENT OF POLICY	
Signed: Print Name: Date:	
Risk Level:Following this assessment the level of risk is now deemend to be: (Acceptable/Unacceptable, further control measures required)	

3. MANAGEMENT SYSTEMS

Maintenance of the safety measures of this risk assessment

4. GENERAL DESCRIPTION OF PREMISES

Description:

Occupancy:		**Size:**	
Times the premises are in use:		Building footprint (meters x meters)	
The total number of persons employed within the premises at any one time:		Number of Floors:	
The total number of people who may resort to the premises at any one time:		Number of Staris:	

5. FIRE SAFETY SYSTEMS WITHIN THE PREMISES

Fire Warning System: (i.e. automatic rifre detection,break glass system, etc)	
Emergency lighting (i.e. maintained/non-maintained, 1hr/3hr furation, etc)	
Other: (sprinkler systems, etc)	
Fire fighting equipment	
Fire extinguishers, hose reels and fire blankets	
Fire Resisting construction	
Identify what fire resisting construction is required to secure the means of escape	
Fire resisting doors must be fitted with self closing devices or kept locked shud, doors must close fully on their stops.	
Fire Exits	
Identify whtat fire exits are required	

PLAN DRAWING
Complete a simple line drawing of the premises and identify the fire safety provisions - including escape routes, estinguishers, emergency lighting and fire alarm.
Identify Ignition and Fuel Sources **Noughts and Crosses** - As an aid to identifying the hazards within the premises it's possible to use a system of nought and crossess, using a X to mark Ignition sources and O for fuel sources.

Step 1 - Identify Fire Hazards	Are existing control measures suitable?

Sources of Ignition	Location	Existing control measurements	YES/NO
Naked Flames			
Heaters			
Electrical Equipment			
Lighting equipment			
Seating materials			
Arson			
Other sources			

If you have anwered NO on any questions above complete the delails below:

What needs to be done to make each situation safe?	Action Required by?	Due date:	Signed complete

Step 1 - Identify Fire hazards (continue)			
Source of fuel & oxigen	Location	Existing control measurements	YES/NO
Wood, paper, cardboard, etc.			
Plastic, rubber, foam (including packging)			
Electrical equipment eg. Overloaded sockets			
Furniture and fixings eg. Curtains			
Flammable gases, liquids eg. Oil, solvents			
Textiles			
Display materials			
Waste materials			
Additional oxygen supplies eg. A/C units			

If you have anwered NO on any questions above complete the delails below:

What needs to be done to make each situation safe?	**Action Required by?**	**Due date:**	**Signed complete**

Step 3 - Identify People at Risk

Why are they at risk?	Location	Control measures	YES/NO
Staff working alone			
People with disabilities (including mobility, hearing, vision impairment)			
Unfamiliar with the building			
Contractors			
Other			

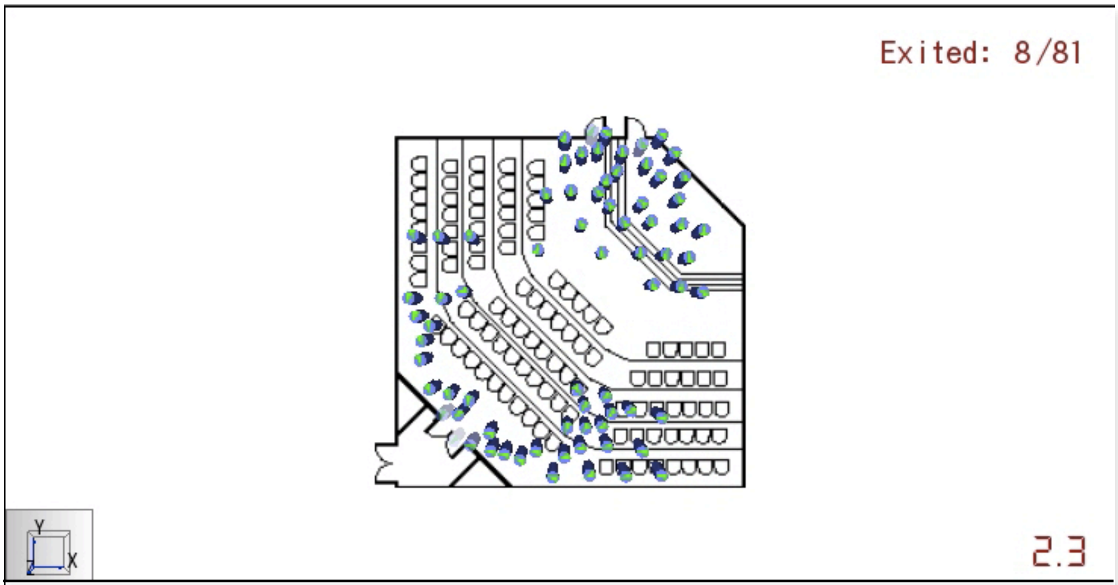
If you have anwered NO on any questions above complete the delails below:

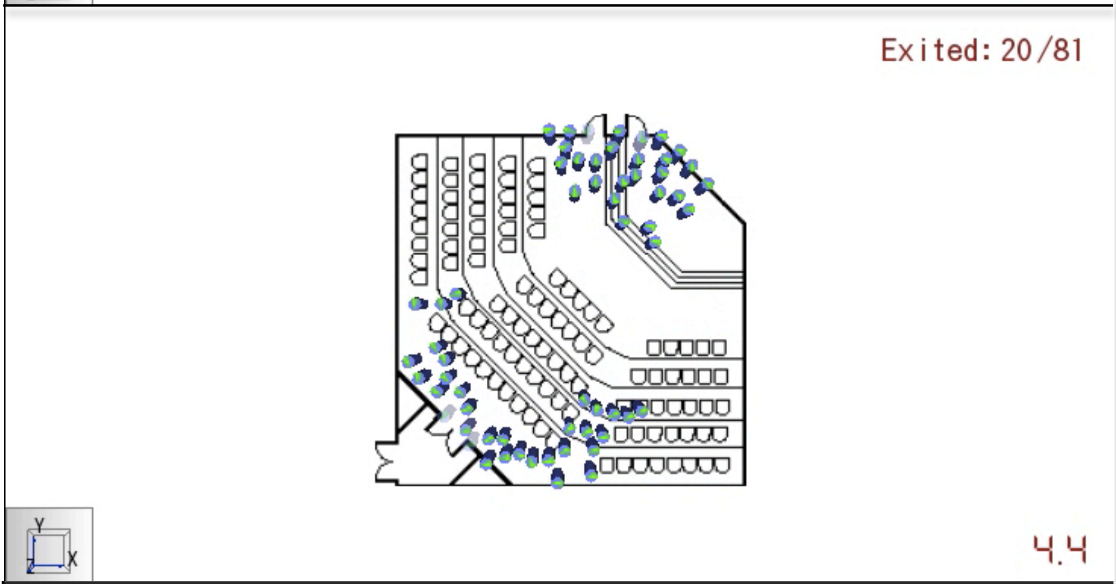
What needs to be done to make each situation safe?	Action Required by?	Due date:	Signed complete

Step 3 - Evaluate, remove, reduce and protect from risk			
Can hazards and risks be removed or reduced?			
The following examples can greatly aid the protection of people and proterty - Separate ignition sources from combustibles Improve security Remove or improve storage of high flammable materials Replace temporary heaters with permanent fixed ones Regularly remove refuse and packing materials Provide automatic fire detection Provide emergency escape lighting Test and maintain all fire safety equipment Arrange electrical testing of appliances			
Evaluate the safety arrangements			**YES/NO**
Are ignitions sources controlled to minimize the likelihood of fire?			
Are cobustible materials kept away from ignition sources?			
Would a fire be discovered quickly?			
Will everyone be warned of the fire immediately?			
Is escape availabe in more than one direction?			
Can everyone escape without assistance?			
Are exits easily identified?			
Are escape routes free from obstruction?			
Are doors to aoutside easy to open?			
Is the alarm sysem tested and maintained in accordance with relevant standards?			
Is the emergency lighting system tested and maintained in accordance with relevant standards?			
Are fire extinguishers serviced in accordance with relevant standards?			
If you have anwered NO on any questions above complete the delails below:			
What needs to be done to make each situation safe?	**Action Required by?**	**Due date:**	**Signed complete**

Step 4 - Record, Plan, Inform, Instruct and Train			
You must record your fire safety arrangements - this includes:			YES/NO
Have you made an emergency plan and does it include the points below?			
Your emergency plan should include -			
How will people be warned if there is a fire:			
What should staff do if they discover a fire:			
How should the evacuation of the premises be carried out:			
Where should people assemble and how to check premises have been evacuated:			
Duties and identity of responsible staff if there is a fire:			
Have you provided instruction and training to staff			
			YES / NO
Has instruction and training been provided to all staff on what to do in case of fire?			
Are there records of fire drills, instruction and training?			
If you have anwered NO on any questions above complete the delails below:			
What needs to be done to make each situation safe?	**Action Required by?**	**Due date:**	**Signed complete**

Step 5 - Review	
Your risk assessment must be kept up to date	
Date of next review: It is recommended to review the risk assessment every 12 months **OR** if changes are made to the layout of the premises, significantly increase the amount of combustioble materials stored or displayed, change the opening hours the risk assessment must be reviewed.	


Exited: 8/81
2.3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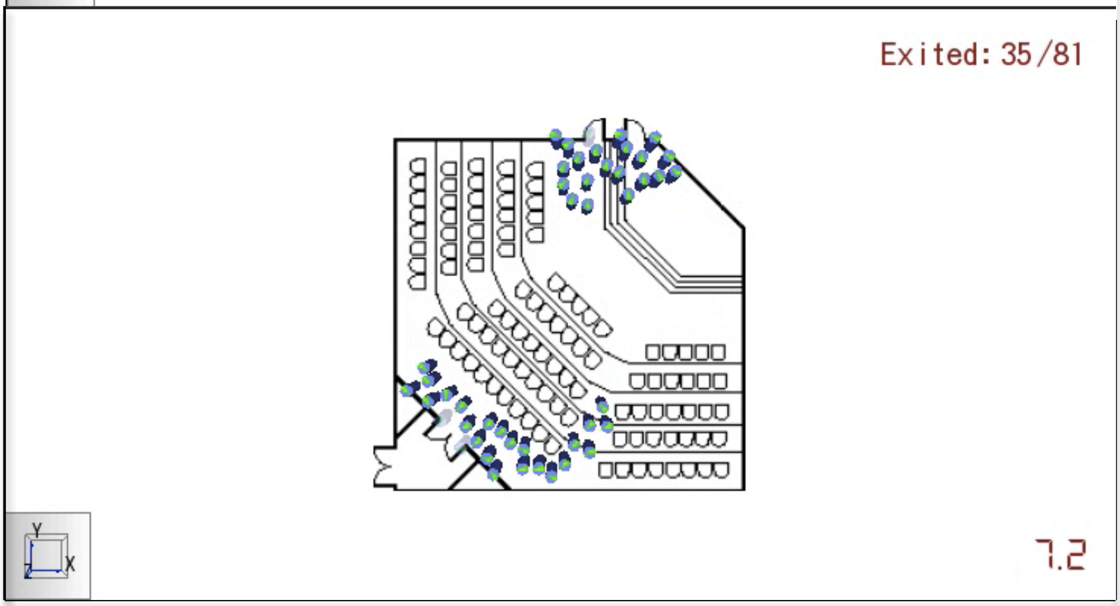
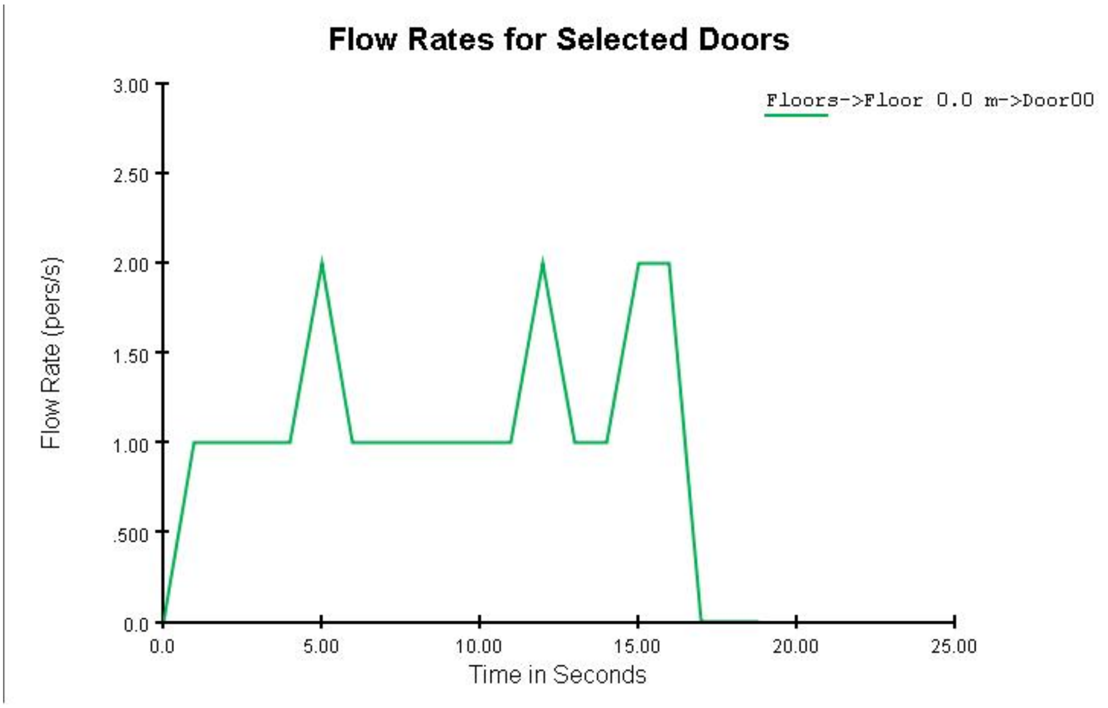
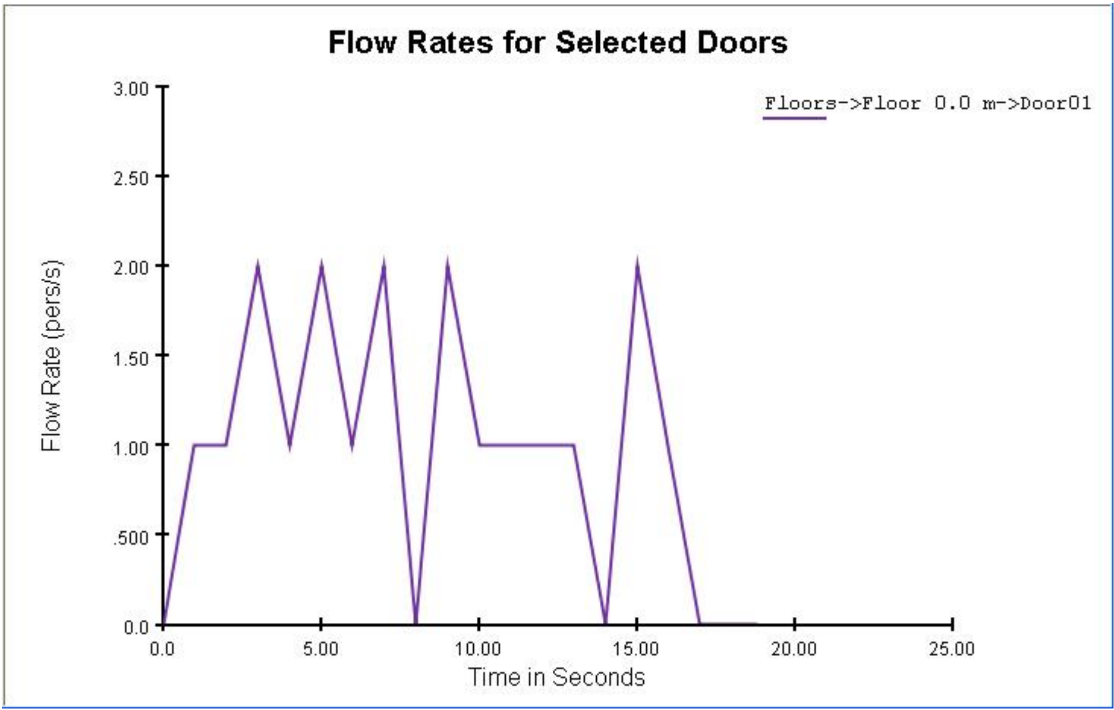
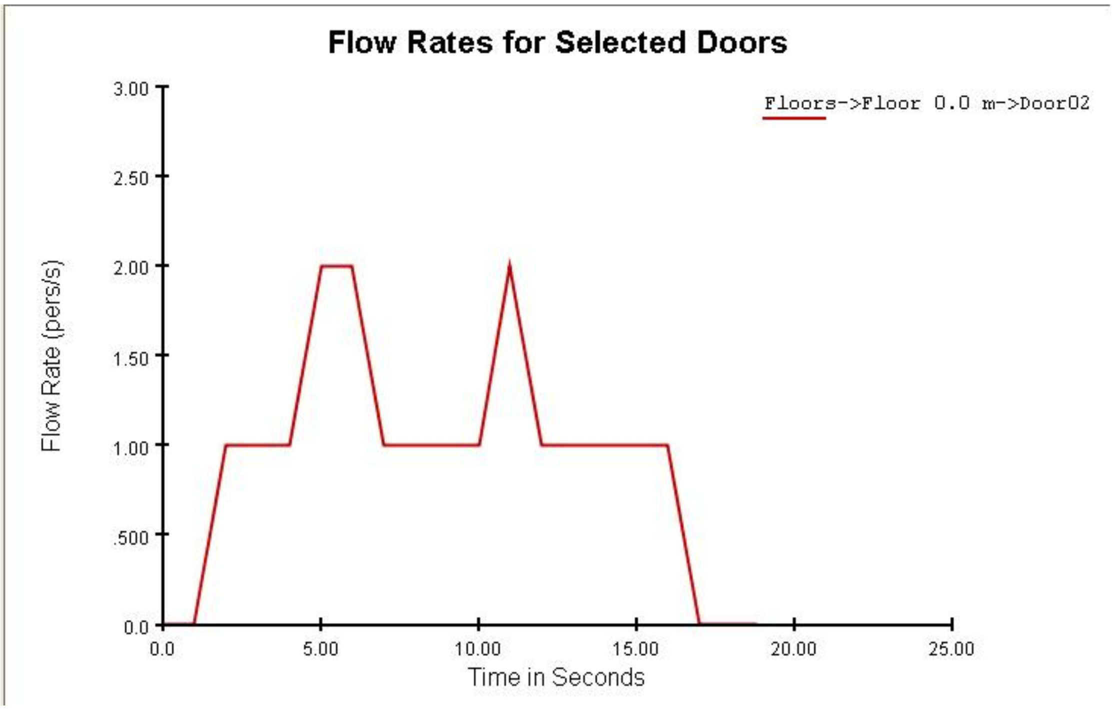
4.4


Exited: 35/81
7.2

DOOR FLOW


Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door00
Flow Rate (pers/s)
Time in Seconds
3.00
2.50
2.00
1.50
1.00
.500
0.0
0.0
5.00
10.00
15.00
20.00
25.00


Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door01
Flow Rate (pers/s)
Time in Seconds
3.00
2.50
2.00
1.50
1.00
.500
0.0
0.0
5.00
10.00
15.00
20.00
25.00


Flow Rates for Selected Doors
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Flow Rate (pers/s)
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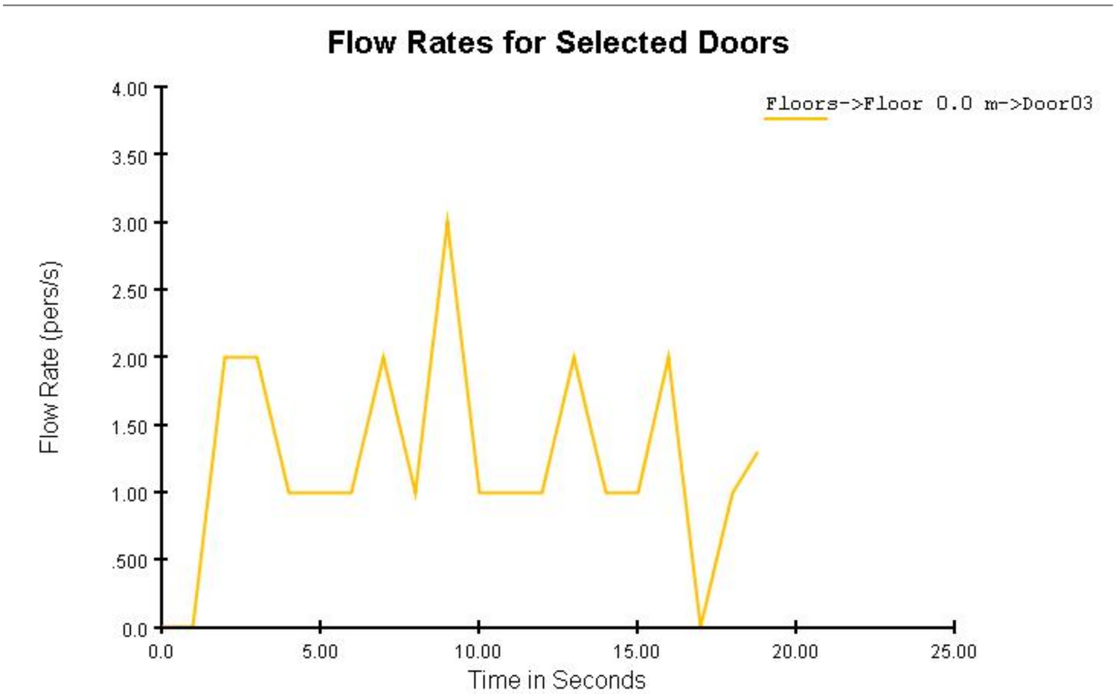
2.50
2.00
1.50
1.00
.500
0.0
0.0
5.00
10.00
15.00
20.00
25.00
Time in Seconds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3.00
2.50
2.00
1.50
1.00
.500
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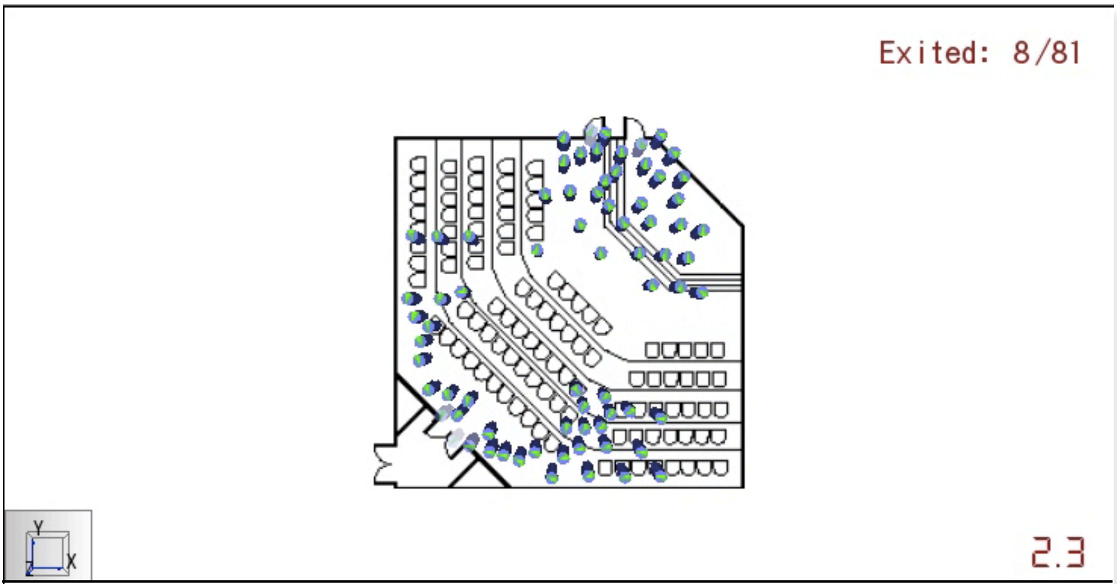
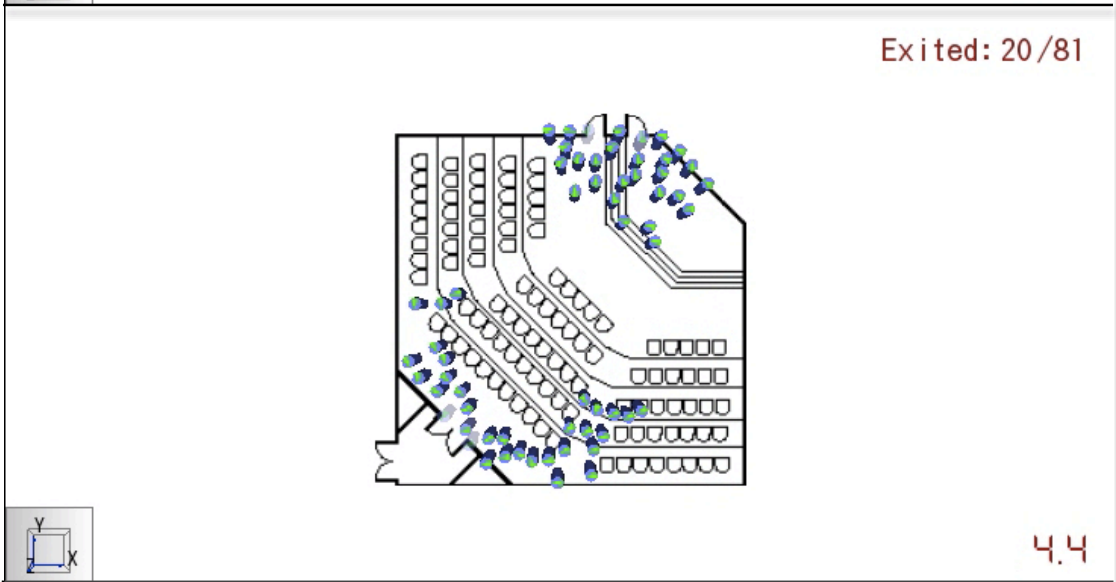
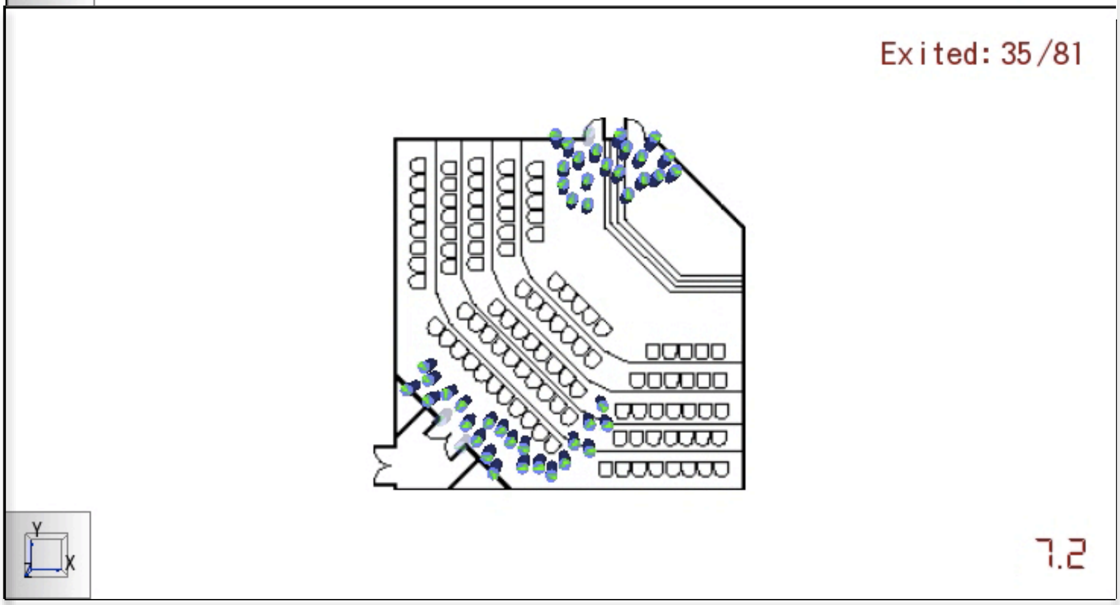
0.0
5.00
10.00
15.00
20.00
25.00
Time in Seconds

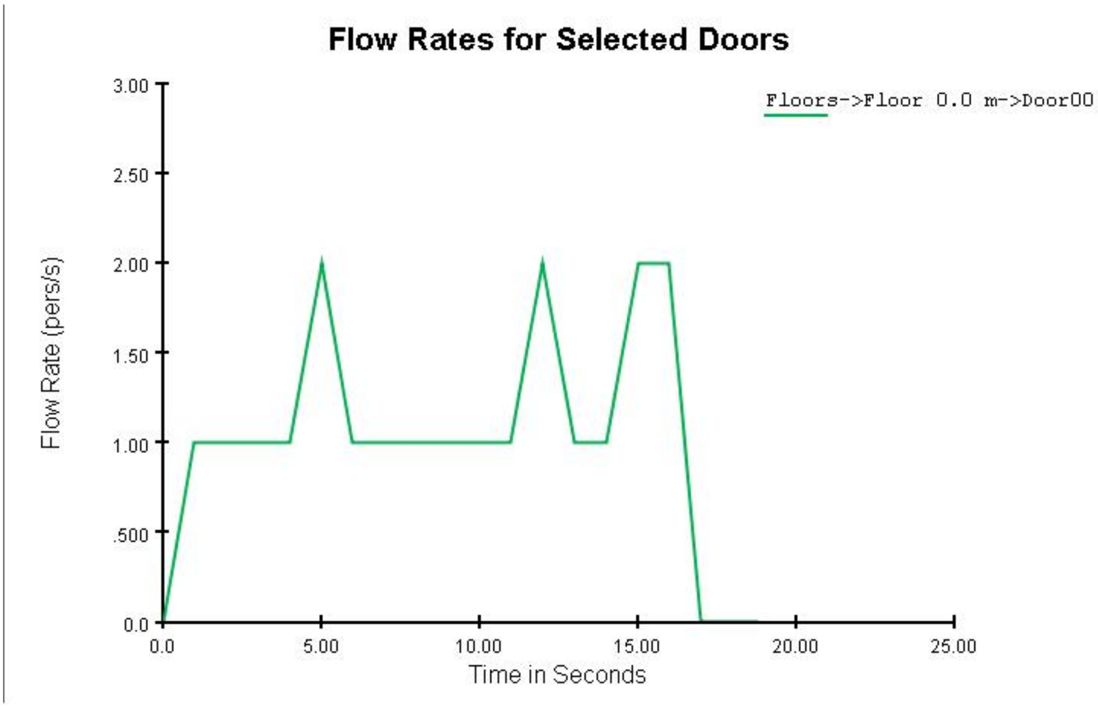
EVACUATION SIMULATION MODEL







DOOR FLOW



Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door00
Flow Rate (pers/s)
3.00
2.50
2.00
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.500
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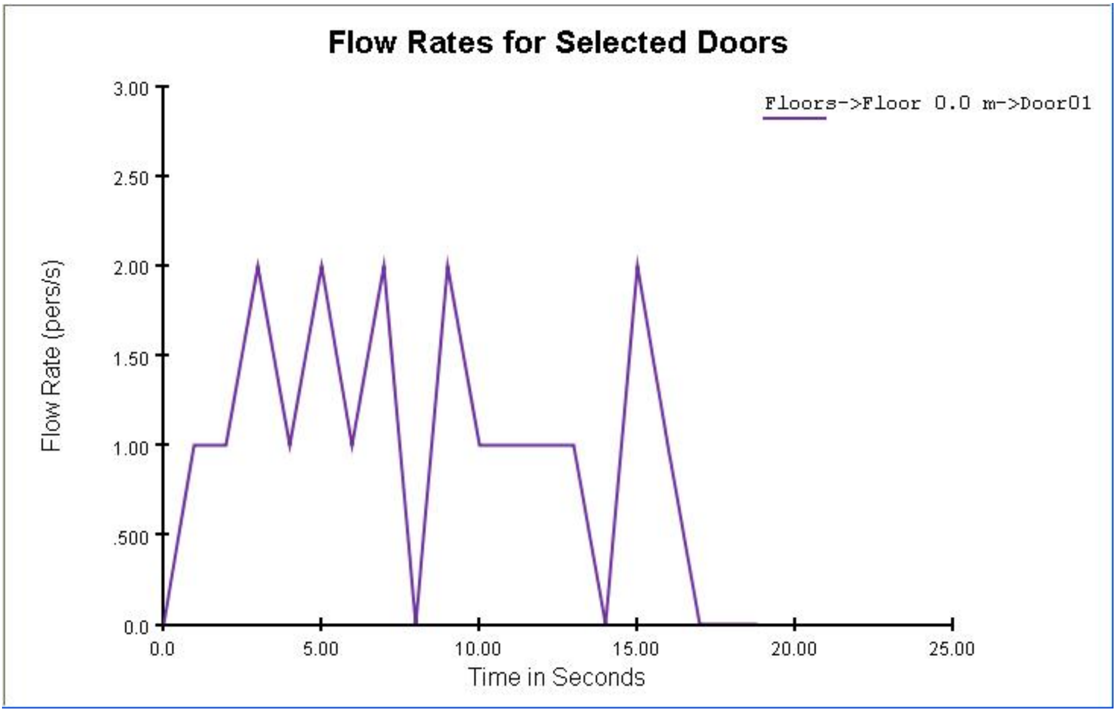
5.00
10.00
15.00
20.00
25.00
Time in Seconds



Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door01
Flow Rate (pers/s)
3.00
2.50
2.00
1.50
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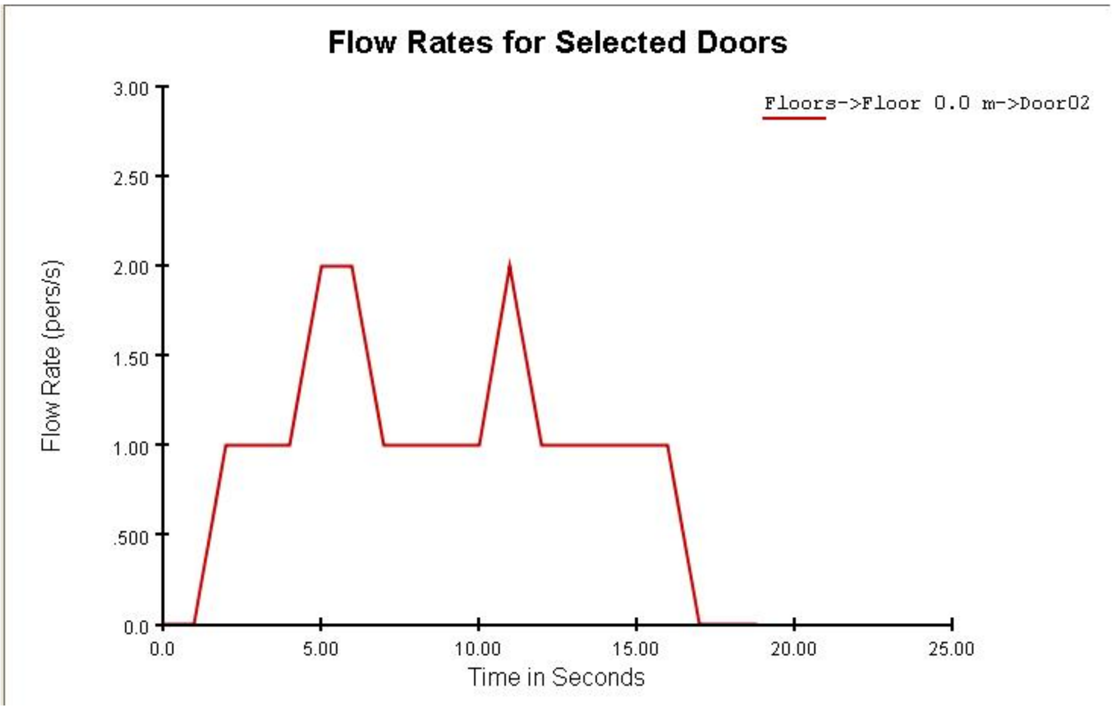
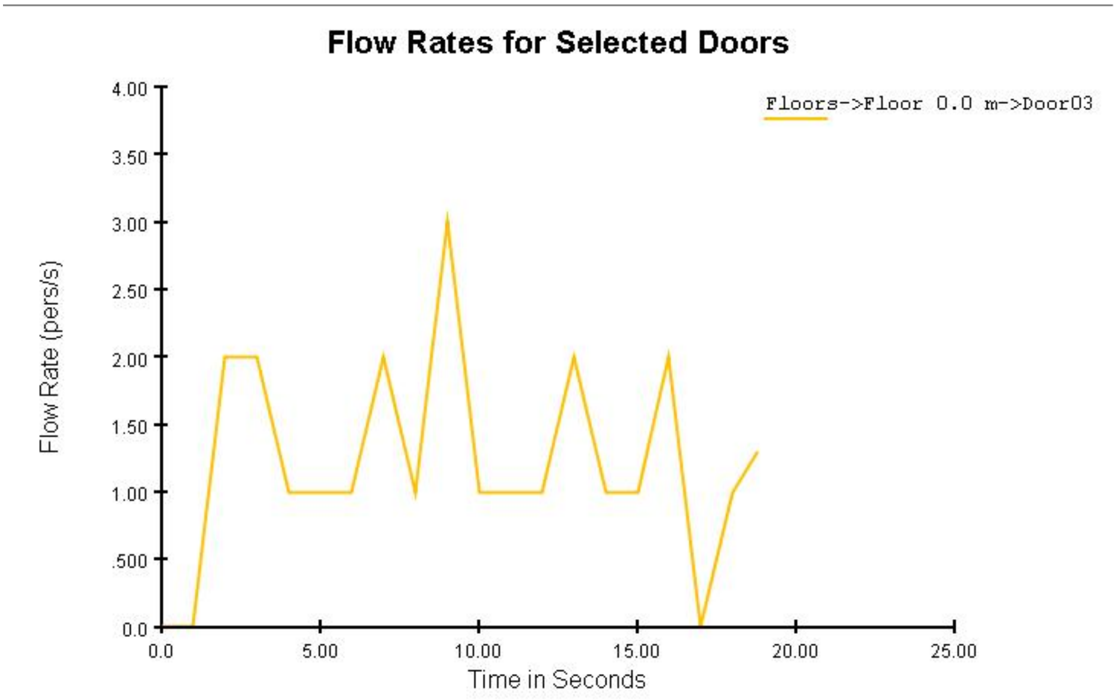
0.0
5.00
10.00
15.00
20.00
25.00
Time in Seconds


Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door02
3.00
2.50
2.00
1.50
1.00
.500
0.0
Flow Rate (pers/s)
0.0
5.00
10.00
15.00
20.00
25.00
Time in Seconds


Flow Rates for Selected Doors
Floors->Floor 0.0 m->Door03
4.00
3.50
3.00
2.50
2.00
1.50
1.00
.500
0.0
Flow Rate (pers/s)
0.0
5.00
10.00
15.00
20.00
25.00
Time in Seconds

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