Doctoral Thesis

Community's Risk Perception and Attitude Towards Landslide Disasters and the Effectiveness of Evacuation Strategy Application

Field Evacuation Practice and Software Simulation for a Neighborhood in La Paz Bolivia - Case Study

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ABSTRACT

The overall objective of this investigation is to provide recommendations to improve landslide risk reduction in La Paz in accordance with the governance structure and institutional and community entities that have been implemented to build resilient communities. A further objective is to design a methodology with which the Municipality can work with the communities incorporating the prevention topic in their daily lives in order to develop a culture of prevention in La Paz City.

This PhD research will present results of empirical data collection to understand the Risk Perception and Attitude Toward Landslide Disasters of a hillside neighborhood, an urban settled area which is at high risk of landslides. This work will describe the living conditions of habitants in this area demonstrating that they are exposed to a combination of natural and social hazards.

The research will show that residents, community leaders and city planners tend to underestimate or deny risk, with important consequences for risk management, such as a failure to raise risk awareness.

Primarily, it is the objective of this work to look at awareness-raising as a core to all disaster mitigation programs, such as implementing disaster preparedness education programs.

Conclusions regarding vulnerability will be presented, measures to be taken and strategies to be made, with a focus on implementing disaster management and preparedness programs in education which specifically deal with risk perception and its consequences on risk management in La Paz.

In this thesis empirical data are presented on evacuation behavior of people and compared to the results of the Agent Based Evacuation Simulation model.

The goal of the practice was to collect data and to perform observations on the evacuation behavior of people in slope movements and on stairs in a real location and environment. Here, speeds and evacuation times were to be collected.

After, this work focused on the evacuation movement of people on stairs in order to provide a better understanding of urban areas egress features and develop a technical foundation for codes and standard requirements as well as egress modeling techniques.

An empirical data analysis and simulation modeling for evacuation movement on irregular non-continuous exterior stairs is given. This data has been collected on a community residents walking behavior on public stairs and steep streets in order to obtain an estimate of the evacuation times so it can be used to test the predictive capability of egress models.

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CHAPTER 1: INTRODUCTION

1.1 Urban development and natural disasters

It is expected that by the year 2050, 66% of the human population will be living in urban cities. The majority of these people are from developing countries (UN 2014). The poorer members of the population tend to live in the most at-risk places, and suffer the greatest losses when a natural disaster occurs. This means that disasters coupled with a lack of sufficient socio-economic resources in developing countries will continue to perpetuate the cycle of poverty in these new urban areas. It is clear that the effects of disasters, those natural and manmade, perpetuate poverty and postpone drastically the national development (CAF 2006).

Over the last years not only urban population has increased, but also frequency and severity of natural disasters (UN-Habitat, 2007). There is a strong relation between urban agglomeration and the occurrence of natural disasters due the massive concentration of people, goods, and infrastructure (Metz/Weiland, 2009).

It is important to consider that the increased concentration of people in cities is not the only reason why urban settlements are particularly vulnerable to the effects of natural disasters. Cities suffer from natural hazards in occurrence and intensity because of different processes that are interrelated, such as rapid urbanization, modification of the urban built and natural environment by human actions, the growth of human settlements within cities into hazard prone areas such as landslides, areas without adequate basic services like water, electricity and a sewer system (Metz/Weiland, 2009; UN/ISDR, 2004; UN-Habitat, 2007).

In a rapid urbanizing world, the reduction of vulnerabilities from the impact of disasters is a global concern in order to achieve sustainable development in all communities (CAF 2006).

A sustainable development is important for developing countries in order to prevent more poverty and support national development programs to protect citizens at risk in a context of rapidly urbanized city areas (CAF, 2006; UNHabitat, 2003(1)).

Disaster risk management is a systematic process focused on building resilient communities by planning for catastrophes in pre-disasters stages, implementing strategies and policies in order to cope and lessen the impacts of hazards and possible disasters occurrence (UN/ISDR, 2009).

Disaster risk management involves different actors and levels where the tasks that need to be done are articulated by the government. Government bodies mediate the interest and differences between the state, civil society and the private sector (Stoker, 1998). Governance goal is to exercise their legal rights and obligations into community development plans in order to create disaster risk reduction (UN/ISDR, 2007).

Government and institution frameworks should provide the proper environment for disaster risk management to succeed (Ahrens/Rudolph, 2006). Institutions play an important role in creating community resilience and reducing risk through procedures, rights and responsibilities of all actors involved (Young, 2002). Besides institutional abilities, an important actor is the community and its abilities to generate a culture of prevention and security reducing risks in the short and long term.

Institutional and community abilities will define how the resilience of a community to natural disasters increase in order to create a sustainable development, especially for poor people living in marginalized areas unable to cope with the damaging effects of disasters. Natural phenomena cannot be prevented, however the impacts can be reduced through disaster risk management. It can influence mechanisms for coping with the effects of a natural hazard (FAO, 2008).

Natural phenomena cannot be prevented, however its impacts can be limited through implementation of an integral process known as Disaster Risk Management system. The primary focus of an action plan dealing with disasters is to generate resilient societies and manage risk (WCDR, 2005).

1.2 Study framework

This work aims to promote the coordination efforts between government bodies and the community to create an environment of information sharing that will allow planners to accurately create strategies and tool for the community in order to reduce risk.

Additionally, this research makes a description related to the perception and attitude a determine community as respect disasters they are exposed to and the management provided by the city government.

La Paz, the administrative capital city of Bolivia in South America, was chosen for this study. Located over the mountain slopes that surround the urban center of the city. This singular and irregular topography plus the illegal rapid urbanization over the mountains with no technical support make La Paz city the ideal research location.

A singular characteristic of the selected area is that in several cases they have public exterior stairs as unique accesses. The configuration and use for these routes are a broad subject not fully investigated yet.

This work presents evacuation guidance, as a way to mitigate disasters risk over those routes. Guiding the people during evacuation increases the effectiveness of the evacuation from a system perspective (Huibregtse, 2013)

1.3 Objectives

This research will provide general concepts of what are the characteristics of an effective landslide risk management, followed by the description of the landslide risk management structure working in La Paz City through an empirical research made to the relevant actor of this structure: the government and the community.

The objective of this work is:

a) To describe the actual situation of the landslide risk management in La Paz.
b) To describe the perception communities have about landslides and the attitude they have towards them.
c) To analyze the government and community abilities and practices related to coping landslides at a community level.
d) To introduce an effective strategy to be applied by the community as a simple and understandable plan for early evacuation.

The main objective is to provide a recommendation to improve landslide risk reduction in La Paz in order to create more resilient societies in accordance with La Paz governance and community capabilities.

1.4 Research methodology

The methodology applied in this research is based on techniques of empirical social research that include data collection techniques, such as practices, interviews and surveys

Results of the empirical data collection will be presented to understand the risk perception and attitude towards landslide disasters of a hillside neighborhood, an urban area that is at high risk of landslides.

The objective of this data collection is to determine what governance structure, institutional and community capabilities are needed to increase the resilience of a community in La Paz City, the administrative capital of Bolivia, where hazards and vulnerability combine in some areas to create risk.

A description of the area that is the focus of this study will be provided, describing its characteristics, the perception of the people in La Paz about disasters and reasons why they still live in areas that are at risk.

Then, some conclusions regarding vulnerability will be presented. Measures to be taken and recommendations will be given, with a focus on implementing disaster management and preparedness programs in educational levels. From this, suggestions will be made on how to adopt and implement a better approach to disasters in education programs in La Paz. The principal suggestion for this work will be the creation of an evacuation strategy to be used in the short term.

To be able to create an accurate and real strategy, empirical data were gathered during announced evacuation practices in a selected neighborhood. The simulation is focused on community residents walking behavior on stairs and steep streets in order to obtain an estimate of the evacuation times.

This work provides details of the data collected, an analysis of the data, and examples of the use of the data. The intention is to better understand movement during evacuations in a determined environment and provide data to test the predictive capability of egress models.

The study area was generated as a 3D model. This was important because of the geographic characteristics of the terrain and the appropriate stairs location.

From the beginning it was necessary to create an accurate environment so the final result would be the closest to a real situation.

The main results of the practices are the movement velocities of people on irregular and non-continuous stairs as principal pedestrians ways in their neighborhood. This parameter is essential because it can be used to obtain a prediction of the amount of time the occupants of an urban area will spend in case of an evacuation.

There are two different approaches in this work related to the evacuation simulation, one is the software strategy which allows the program to choose the shortest path as a primary evacuation route. The second approach is a recommended one, of which the criteria and the final purpose are the same, to evacuate the area. However, the shortest path is not the primary action, but the more effective and safer alternative.

Finally, results are shown in a simulation, showing that when there is a strategy in an evacuation process, evacuation proceeds in a fluid and controlled manner. With this, lower levels of stress and panic are presumed in people's behavior when moving to a safe area, making the evacuation more effective

The approach presented in this thesis offers the possibility to evaluate a given neighborhood configuration considering the multiple possibilities of evacuation route choices.

The simulator generated the shortest distance for an evacuation strategy, using a combination of parameters to select their current path to an exit or safe area.

After running the simulation with data taken from the practices, the overall objective is to provide recommendations to improve landslide risk reduction in La Paz in accordance with the governance structure and institutional and community entities that have been implemented to build resilient communities. A further objective is to

design a methodology with which the Municipality can work with the communities incorporating the prevention topic in their daily lives in order to develop a culture of prevention in La Paz City.

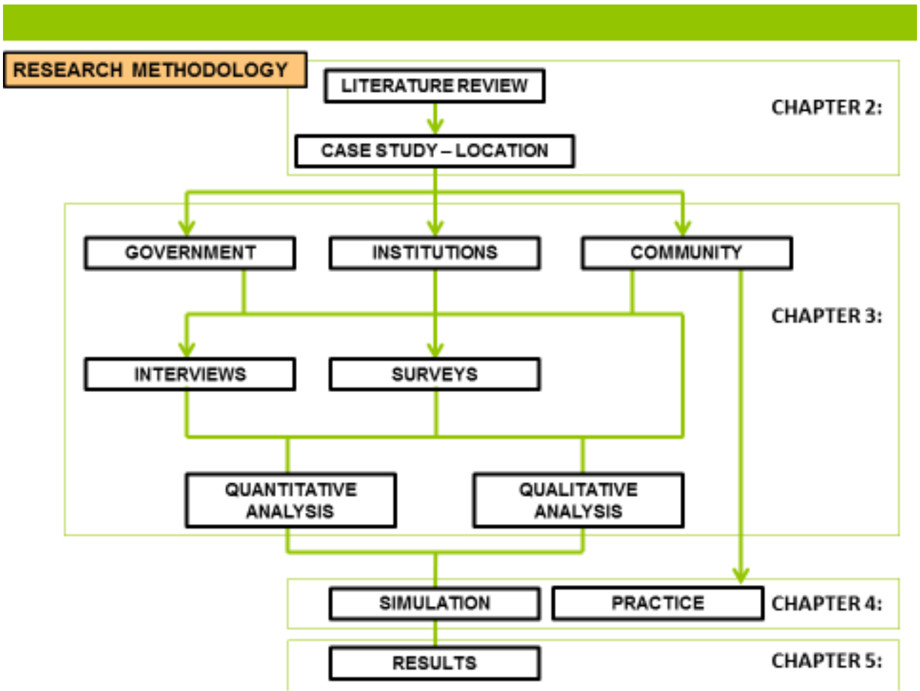


Figure 1-1 Research methodology diagram

1.5 Organization of the thesis

The following chapter provides background information to contextualize the research question and supply the history and terminology related with urban growth, urban disaster risk, vulnerability, disaster risk management, role of governance, institutional and local abilities, evacuation and evacuation on stairs, to provide necessary background for the following chapters. To focus on disaster risk management in La Paz City, a background section will follow in chapter 2 to introduce some general characteristics of the metropolitan area, the demographic patterns, hazard exposure and vulnerability to risks in this location. Chapter 3 will present the following data compilation obtained on field trips. Chapter 4 will present the details about the practice and simulation data process. Chapter 5 will present the results of the analysis and the processes by which the data was obtained. Chapter 6 presents conclusions from the research and recommendation to improve disaster risk reduction in developing countries with the same characteristics as La Paz City in accordance with the institutional, community and governance abilities to build resilient communities.

CHAPTER 2: BACKGROUND INFORMATION AND LITERATURE REVIEW

2.1 Hazards, vulnerability and disaster risk

Disasters -storms, earthquakes, tsunamis, floods, landslides, among others- happen when natural hazards occurring in the biosphere, have the potential to become a damaging event when they impact people and assets susceptible to their destructive effects (UN-Habitat, 2007; Lewis/Mioch, 2005). A natural hazard becomes a disaster risk when there is the likelihood that humans will be seriously affected by this hazard.

Definitions of risk are commonly probabilistic in nature as they relate either to the probability of occurrence of a hazard that triggers a disaster, or the probability of a disaster and the likely consequences of the hazard (Brooks, 2005). In this context, and as stated by the United Nations Office for Disaster Risk Reduction, vulnerability is defined as the "conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impacts of hazards" (UN/ISDR, 2009). Therefore, risk can be understood as a function of hazard and vulnerability.

Hazard x Vulnerability = Risk

The condition for the existence of risk is the vulnerability to the hazards posed by a natural event. Furthermore, the scale of a disaster depends not only on the magnitude of the hazard event, but also on the related human-environmental systems where vulnerability resides (UN-Habitat, 2007; Turner et al., 2003).

Since the 1970's, the damages sustained from disasters have been diverse, including the loss of lives and injuries to people, physical damage to infrastructure and buildings, as well as environmental damage; resulting in the loss of environmental stability, and economic damages (UN-Habitat, 2007).

Between 1974 and 2003, 6367 natural disasters occurred globally, causing the death of 2 million people, leaving 182 million people homeless, resulting in approximately US$ 1.38 trillion economic damage (UN-Habitat, 2007).

2.2 Disasters in Latin America

According to UN Habitat data UN-Habitat, 2008 during the 20th century, urban populations have increased from 220 million to 2.8 billion. The growth rate of cities was at 1.83 percent from 1990 to 2000, and it is expected for the next decades, that there will be an unprecedented scale of urban growth, reaching almost 5 billion in 2030 and 6.4 billion by 2050 (UN-Habitat, 2008). However, this increase in urban population is not happening in an evenly manner; the rapid increase in the urban share of total population, or urbanization, is unfolding faster in developing countries, receiving an average of 5 million new residents every month compared to the 500,000 in developed nations (UN-Habitat, 2008).

Cities are growing and with them the threats they are exposed to. Inadequate urban management in not sustainable urbanizations creates pressure on urban residents (UNFPA, 2007). Cities are becoming unequal, particularly among less developed regions. Wealthy neighborhoods with all services are often located near dense peripheral communities that in general lack basic services.

In Latin America, three-quarters of the population live in urban areas; it also accounts for having some of the most unequal cities (UN-Habitat, 2008). Brazil is at the top of the list, with cities like São Paulo and Rio de Janeiro, followed by Mexico City in Mexico, and Buenos Aires in Argentina. Other cities that ranked in the list include Chile, Ecuador, Colombia, Bolivia and Guatemala (UN-Habitat, 2008).

Latin America, and more specifically the Andean countries, are no stranger to natural disasters; these events are attributed to multiple natural geological and hydro-climatic process associated to the region’s history. Nevertheless, there are other human induced factors that have negatively impinged upon the region’s developmental sustainability and are associated with the occurrence of natural disasters: patterns of land occupation, population vulnerability and economic activities during the development process. (CAF, 2006). The number of people living in urban areas under poor conditions was nearly twice than in rural areas (CEPAL, 2007).

Many of urban expansion settlements in Latin America have taken place over flood-plains or on mountain slopes, or in other areas not suited to settlements, including flooding or landslide prone areas or regions vulnerable to weather related risks. (Hardoy/Pandiella, 2009; IPCC, 2001). When natural areas are transformed into new human settlements, the infiltration capacities are reduced, and deforestation and erosion increased. This, together with the expected increase in scale, intensity and frequency of rainfall, impacts severely the drainage systems, not sufficient to timely evacuate the increased water masses, leading to periodic flooding and landslides on geologically unstable slopes (UN-ISDR, 2002; Bigio, 2003).

The most dangerous sites are inhabited by low-income groups in neighborhoods with high population densities commonly referred to as urban slums (Hardoy/Pandiella, 2009). The UN Habitat 2008 provided criteria to define urban slums; it mentions that "urban slums often lack one or more of the following conditions: access to improved water, access to improved sanitation facilities, sufficient living area, structural quality and durability of dwellings, and security of tenure" (UN-Habitat, 2008). In addition, these settlements are frequently located in sites prone to natural hazards, nearby rivers or on steep slopes, the only sites where low-income groups find housing they can afford or where they can build their homes, (Hardoy/Pandiella, 2009; UNHabitat, 2008). As a consequence, an increasing number of informal human settlements are turning into potential hotspots for disaster risk (UN-Habitat, 2007).

2.3 Vulnerable cities

A disaster is a function of risk processes, and a result from a combination of the probability of occurrence of hazardous events, human vulnerability to the effects of the hazard, and the insufficient capacity to reduce the potential negative consequences of risk (UN-Habitat, 2007). Urban growth in cities increases the risk produced by natural disasters as urban centers continue to expand to more vulnerable areas. (Lavell, 2000).

In urban contexts, vulnerability is socially constructed and it is affected by a complex set of interrelated processes. One of these processes is the concentration of assets, wealth and people in cities. The impact of natural hazards will thus be higher in areas where the population is concentrated in limited areas contrary to areas where the population is dispersed (UN-Habitat, 2007).

When cities cannot cope with rapid population growth and high demand for land, poor people settle illegally in unsuitable terrains, such as floodplains, reclaimed land, industrial waste sites, riverbanks and steep unstable slopes which are prone to natural hazards and most vulnerable to the impacts of disasters (UN-Habitat, 2007). The United Nations Populations Fund reports that over half of the urban population in many developing countries is below the poverty line and are relegated to these socially segregated areas referred to as informal settlements with inappropriate construction and with limited or non-existent basic services infrastructure (UNFPA, 2007). These settlements live in deplorable urban housing conditions - lack of basic services, water, sanitation, electricity, solid waste disposal, etc - and insecure living conditions generating greater hazards.

The number of these settlements is growing alarmingly all around the world (Leeds/Leeds, 1978) (UN-Habitat, 2007). These slums are the home of the poor in urban areas who struggle to survive and therefore these areas have high concentration of poverty and also social and economic deprivation (UN-Habitat, 2007). Poverty increases people’s vulnerability to natural hazards and disasters worsen the already precarious living conditions. Even a low intensity hazard is capable to attain disastrous proportions when it hits poor communities living in such risky conditions with a limited capacity to withstand disasters (Wamsler, 2007).

The human induced modification of the urban built and natural environment is also a factor of the risk process. The construction of a city implies a change from a natural environment into a social and constructed environment. These changes in urban development changes ecosystems, through the consumption of natural assets and overexploitation of natural services, increasing the possibilities of new hazards and natural disasters.

The UN Habitat 2007 Report, provides several examples of human caused changes in ecosystems and their concomitant impact human life: deforestation has led to hillside erosion making people vulnerable to landslides caused by heavy rains, shortage of appropriate drainage systems making cities vulnerable to flash floods, and loss of mangrove ecosystems on urban fringes leading to coastal erosion and exposure to storm wind and waves (UN-Habitat, 2007).

Another factor that increases vulnerability of cities to disaster risk is the failure of authorities to regulate land-use planning strategies, urban development and building standards. In the absence of such controls and regulations, unsaved construction and land-use planning practices will increase and generate even greater vulnerability.

As it can be seen, disasters in urban areas are not natural events, but socio-environmental events that are the result of socially constructed risks (Cardona, 2004). Hence, disaster risk is the product of inappropriate and failed development, institutional failure, deficient urban management practices, ecological imbalance, and inadequate land-use planning, among others (Lewis/Mioch, 2005; Ahrens/Rudolph, 2006).

2.4 Post-disaster to a pre-disaster approach

The established approach to face disasters has been based on emergency management with a response focus. Before the 90s, attention was placed primarily in humanitarian emergency response to any disaster that happened (Basabe, 2007). However modern societies cannot afford to value human lives and material assets only after they have been lost in a disaster. The role of relief assistance should not be underestimated but more attention needs to be paid to protective strategies that could help to save lives and to protect property and resources before they are lost (UN/ISDR, 2004).

During the International Decade for Natural Disaster Reduction (IDNDR) in the 90's, the focus was on reducing the consequences of natural disasters and building a culture of prevention. The approach evolved from a reactive one to a proactive approach. Science and technology played a key role in generating knowledge for disaster reduction and developed the decision making processes. However, the increased number of disasters brought more casualties, economic damage and suffering by the end of the decade. Fundamental problems in understanding and managing risk factors reiterated the need of hazard awareness and risk reduction activities to educate and engage people. (UN/ISDR, 2004).

After 2000, the successor of the IDNDR was the United Nations International Strategy for Disaster Reduction (UN/ISDR). The aim was twofold: first, to enable societies to be resilient to natural hazards, and second, to ensure that development efforts do not increase vulnerability to those hazards. This means to build resilient communities by promoting increased awareness of the importance of disaster risk reduction as an integral component of sustainable development.

Disaster risk reduction thus, became a developmental concern. It involved all the actions and systematic efforts to analyze and manage the causal factors of disasters, including the following:

i. Reduced exposure to hazards;
ii. Minimize vulnerability of people and property;
iii. Wise management of land and the environment;
iv. Improved preparedness for adverse events throughout society (UN/ISDR, 2009).

In that spirit, 168 countries and organizations adopted the Hyogo Framework for Action 2005-2015 in January 2005. This plan was aimed at building a safer and more disaster-resilient world; to that end, it recommended 5 priority actions and reiterated the need for a multi-stakeholder involvement and national coordination for mainstreaming disaster risk reduction into policies, planning and programs.

2.4.1 Disaster risk reduction

Disaster risk reduction is found within the broader concept of disaster risk management defined as "the systematic process, organization, operation skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related disasters" (UN/ISDR, 2009). This is an integral multi-sectorial and multi-disciplinary process of planning and implementing pre- and post- disaster activities. It is focused on actions that help prevent, mitigate or prepare for risks (ex ante) while at the same time considers the importance of immediate responses and post-disaster recovery and rehabilitation (ex post) (Metz/Weiland, 2009; Vermaa/van Niekerk, 2004).

The purpose of disaster risk reduction is to reduce the main factors of risk and to prepare for an immediate response in the case of a disaster (FAO, 2008).

2.4.2 Governance, institutional and community abilities to increase resilience

Not only a group or organization can address by itself all the phases of disaster risk management. Being such a complex task, it requires a collective response from different disciplinary and institutional groups (Twigg, 2007).

In this sense, disaster risk management harnesses the synergies from actors in different stages. Prevention and mitigation measures for instance, require the involvement of disaster risk reduction actors. In like manner, preparedness and response need the involvement of humanitarian actors, while recovery and reconstruction requires the work of sustainable development actors (Metz/Weiland, 2009). All of these actors can come from the public sector, international organizations, technical and professional bodies, NGOs, and other civil society organizations.

Governance is considered as a key aspect, and its salience has been acknowledged by the Hyogo Framework for Action, when it recognizes the importance of the relationship among different actors in strengthening governance. Governance is associated with new forms of socio political interaction, in other words, the interaction of a multiplicity of governing each other and influencing actors, mainly the state, civil society and the private sector (Stoker, 1998). The interaction between these relatively autonomous domains harness collaborative process with various forms of mechanisms or institutional arrangements that contribute to the implementation of disaster risk policies and development sustainability (UN/ISDR, 2009).

Therefore, for an adequate disaster risk management, a governance structure is paramount. This governance structure, through an institutional matrix in which individual actors, social groups, civil organizations and policy makers interact with each other, facilitating the operationalization of the different phases of the disaster risk management cycle and influencing communities positively or negatively (Ahrens/ Rudolph, 2006; FAO, 2008; King, 2008).

Society manages its development, resolves conflicts formally and informally. It makes decisions through institutions and processes related to governance structures that can affect any initiative in disaster risk management and reduction (Twigg, 2007).

In this research the term institutions are applied to organizations that define rights and responsibilities of the different actors involved, guide interactions and facilitate the coordination among them.

Institutions are formed by the ones creating the rules and the ones that follow those rules. Rules are norms, values, traditions and legislation that determine how people should behave; the ones that follow them are the organizations and their capacities to operate according to those rules (FAO, 2008).

2.5 An effective landslide risk management

Different studies and literature review related to an effective landslide risk management in urban areas were gathered and analyzed. Three phases of an effective disaster risk management are presented next. They are pre-disaster, response and post-disaster. The main components are summarized in the following figure.

This section will emphasize those points and concepts related to the main objective of this investigation.

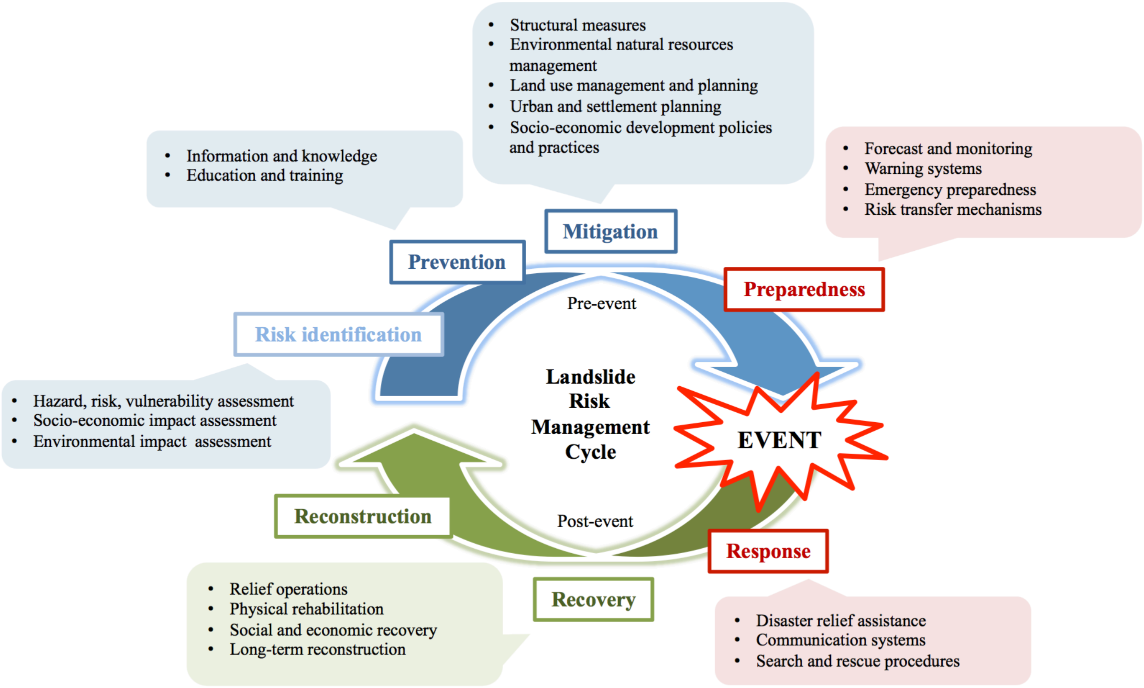


Figure 2-2 Components of an effective disaster risk management

2.5.1 Pre-disaster phase

2.5.1.1 Risk identification

For this specific study, it is important to better understand landslides hazards through a rational risk management in order to effectively mitigate them.

Generating knowledge on the different types of vulnerability (physical, social, economic and environmental) of a society to a landslide hazard is the cornerstone of an effective landslide risk management scheme. (UN-Habitat, 2007).

2.5.1.2 Prevention, Education and information

Communities and institutions develop programs and preventive measures to generate landslide reduction (Anderson et. al., 2006). These measures and programs consider different elements for its development. Education and information are important elements considered in this study.

Education for awareness, both formal and informal, is the vehicle for empowering communities living in vulnerable areas and for reducing the number of people affected by landslides (Karnawati/Pramumijoyo, 2008). The education of communities and disaster risk reduction decision-makers, could also yield another positive result: increased collaboration between risk aware communities and governments to take further measures to improve resilience to landslides. (Anderson/Holcombe, 2008).

With the purpose of enhancing school students' understanding of geological hazards, some Asian countries have already introduced basic knowledge on geology into their formal education curricula. However, the impact of this measure on students' awareness and preparedness to risk and hazards is yet to be proven (Karnawati/ Pramumijoyo, 2008).

Information improves awareness and generates knowledge regarding disaster risks, it constructs a culture of safety and resilience at all landslides risks levels and empowers the society to adapt with the geological conditions they live on. In order to achieve public awareness and preparedness it is important to create a link between the source and the receiver of the information.

This information must be disseminated and reach all the society through different mass media, such as television, radio, internet, as well as through several activities and programs created by formal institutions (Karnawati/Pramumijoyo, 2008).

2.5.1.3 Mitigation and risk reduction

Earthwork altering the slope geometry and loading slopes with buildings and infrastructure, variations in the surface water and groundwater regimes as well as changes in vegetation, increase landslide risk.

When the landslide risks or susceptible areas are identified, and information about what causes the disaster is available, strategies to reduce and mitigate disaster risk are applied.

2.5.1.4 Preparedness

One important components of a disaster risk management before a hazard event is disaster preparedness. Preparedness actions include monitoring and warning systems that serve as a strategy to reduce the impact of expected elements at risk by evacuation in advance, emergency preparedness, and risk transfer mechanisms.

2.5.2 Response phase

When a landslide occurs, the response phase goal is to reduce to the minimum the damages to people's life and satisfy their basic needs. During an emergency, it is necessary that organizations providing first aid and more importantly, apply suitable and organizational procedures and logistics for a technical rescue in order to save the highest numbers of human lives involved in a landslide (Longoni/Papini, 2008).

2.5.2.1 Evacuation

Evacuation is an important response tool applied by the community authorities in order to manage the consequences of a natural disaster, (UN,2014).

It is necessary to develop emergency plans to protect the community and their property; these plans should be based on a pre-established evacuation plan, where safe areas and paths have previously been identified (CAF, 2006). To the same extent communities must get proper preparation and training to allow them to appropriately and rationally face a dangerous situation to mitigate the impact of a disaster (CONF, 2013).

One of the applications for any emergency plan is to prepare in advance for evacuation of an affected area (Rathi/Solanki 1993). Being this an effective protective action, through them, it is possible to train and sensitize the population about the presence of a real emergency, the right decisions in such situations are vital (Cuero 1995) and the time they use to accomplish this action is essential.

Evacuation time, which may be either total evacuation time or network clearance time, is one of the primary concerns of an evacuation plan. Total evacuation time refers to the sum of individual evacuation time over the whole evacuating population in a given emergency area. Network clearance time is a more straightforward time indicator, denoting the time it takes to evacuate the last people since the evacuation onset (DEGIR, 2012).

2.5.2.2 Evacuation on stairs

Evacuations from steep slopes appear to be different from those in better conditions like flat and horizontal areas, causing longer evacuation times due to difficulties in moving down or in some cases up and other delays not attributable to interaction.

The time that it takes an occupant to reach safety when descending or ascending stairs during an evacuation is in general estimated by measuring different variables such as stair geometry, speed, stair density, and pre-observation delay. These variables are used in evacuation models in order to predict the performance of those who will follow the egress system (Nathan, 2008).

Movement speeds of occupants walking down the stairs are seen to vary from average movement speeds, which are observed to be quite similar to the range of values in previous studies.

The movement time through the different routes to the final exit is the sum of the time that each occupant will use to evacuate the affected area.

To calculate the movement time, it is necessary to know the walking speed and the occupants' behavior; all this placed over different components that generate the escape route, like stairs, doorways and slope streets (Candinas, 2007).

As movement on stairs during evacuation plays a very important role, this work will cover stairs characteristics, occupant movements during evacuation, their behavior and some related problems.

This work provides data on evacuation-related people movement on slope streets and stairs in a neighborhood located on a high risk slope area in La Paz city of Bolivia. The final phase of the evacuation process in the model proposed is concerned with an action of leaving the affected area.

2.5.3 Post-disaster phase

This is an important stage of an effective disaster risk management since this will allow the affected community to mitigate and recover from crises as well as to prevent lapsing back into crisis by ensuring a longer term developmental strategy.

When a disaster occurs, the affected human settlement needs a post-disaster relief operation. This rapid rehabilitation is not linked to an overall long term development and represents only a financial and human resource invested in a short sighted emergency relief.

What is needed is a recovery and reconstruction process for sustainable development that will offer to societies the opportunity to strengthen and promote social safety nets to facilitate economic, social and physical development long after a disaster.

A recovery process is a long-term reconstruction development, economic recovery, and restoring people’s livelihoods. This process continues for a longer time after the disaster, reconsiders past strategies and creates policies affecting disaster-prone areas in order to build a better development structure (UN-Habitat, 2003(2)).

2.5.4 The role of the government

The public sector needs to acquire some development in order to implement risk reduction policies, action that needs to become a national and local priority and then promote accountability in all levels of public authority (UN/ISDR, 2004).

The governance plans and regulates frameworks that proactively facilitate access to safe land, housing, infrastructure and services for the urban poor providing secure land with that create more resilient cities (UN/ISDR, 2009). With this approach, countries or cities must develop or modify policies, laws, and organizational arrangements to integrate disaster risk reduction into development planning (UN/ISDR, 2005).

2.5.5 The role of institutional and community abilities

Disasters are not the result of a hazardous event only, they are also linked to vulnerabilities that the exposed elements present and the abilities within the society to cope with them.

Communities do not exist in isolation, and their resilience is influenced by external actors like emergency management service, social and administrative services, public infrastructure and a web of socio-economic and political interactions with the world (Twigg, 2007). These outside capacities are the institutional capacities and represent the enabling environment. The convergence of institutional and community capabilities systematically build resilience (UN/ISDR, 2007).

2.5.6 Coordination and organization abilities

Coordination must be both horizontal and vertical because the local levels are part of the global and therefore it establishes close relationships with other regional levels.

2.5.7 Public involvement and commitment abilities

Public participation is very important because it can generate accountability, credibility and legitimacy. Accountability is the means to more open, transparent and responsive institutions. It increases trust in public institutions that facilitate the implementation of disaster risk management measures. When public institutions are not trusted, warnings and evacuation notices can be ignored by local representatives and by the community (Lebel et al., 2006).

2.5.8 Information and communication abilities

Information and communication are essential to raise awareness of decision-makers and to promote a culture of prevention in the community. Access to information, incorporate and exchange knowledge and experiences between other sectors for efficient and effective decision-making promote attitudes of prevention and self-responsibility among all actors.

2.6 Study Location

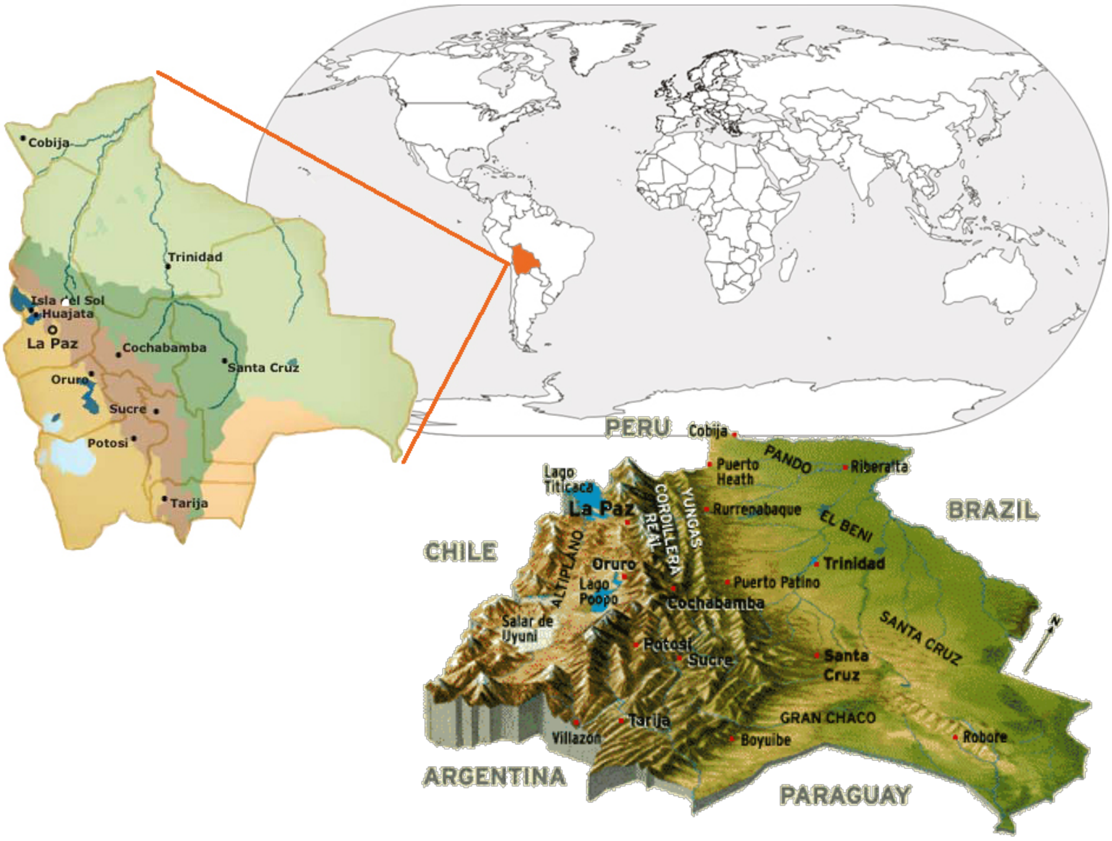


Figure 2-2 La Paz, Bolivia location

2.6.1 Geographic location and territorial structure of La Paz City, Bolivia

La Paz, administrative capital of Bolivia is located on the western side of Bolivia at an elevation of 3,650 meters above sea level. The city is the capital of La Paz Department that has a total area of 472 km2 and the urban area is 3,240 km^2.

The city sits in a bowl shape location surrounded by the high mountains of the Altiplano. As it grew, the city of La Paz climbed the hills, resulting in varying elevations from 3,200 to 4,100 m (10,500 to 13,500 ft). Overlooking the city is towering triple-peaked Illimani, which is always snow-covered and can be seen from many parts of the city (Morales, 1995).

As of the 2012 census, the city had a population of 10.027.254 with a density of 9.13/km^2.

Located at 16°30′0″S 68°08′0″W(−16.5, −68.1333), La Paz is built in a canyon created by the Choqueyapu River (now mostly built over), which runs northwest to southeast (Andinas, 2007)).

The irregular topography surrounded by mountains and the lack of flat land has conditioned the urban structure of La Paz (EMI, 2005).

The activities and functions within this territory are strongly determined by three main geographical structures of the municipal territory: compact in the central city, scattered in the suburban valleys, and isolated in the rural areas (MDMQ, 2006).

The city center is bordered by high slopes and extends along a north–south axis. The eastern and western laderas (hill slopes) that surround the city are densely urbanized and are angled at more than 50 degrees (Nathan, 2008).

2.6.2 La Paz demographics

Of the 10,027,254 inhabitants registered in the country, 6,751,305 live in urban areas and the remaining 3,275,949 in rural areas, in percentage terms this means 67.3% and 32.7%, respectively, according to the National Population and Housing census 2012, conducted by the National Statistics Institute.

As in many cities in South America, La Paz also reflects the trend of rapid urbanization due the continued migration to the city, lack of effective urban planning, and government decentralization which adds pressures on municipalities in dealing with urban management and provision of services (Fernandez et. al, 2006).

In Bolivia, the urbanization process was initiated between 1973 and 1992, when urban areas come to have greater population than rural areas. The growth of cities accelerated in the early 1980s. The slopes and edges of rivers are new spaces occupied by the rapid growth of the city. The occupation of these spaces generates disasters in places never before perceived as dangerous. Space monitoring aerial photographs and satellite imagery can explain what is the pattern followed by people to build the city in dangerous areas.

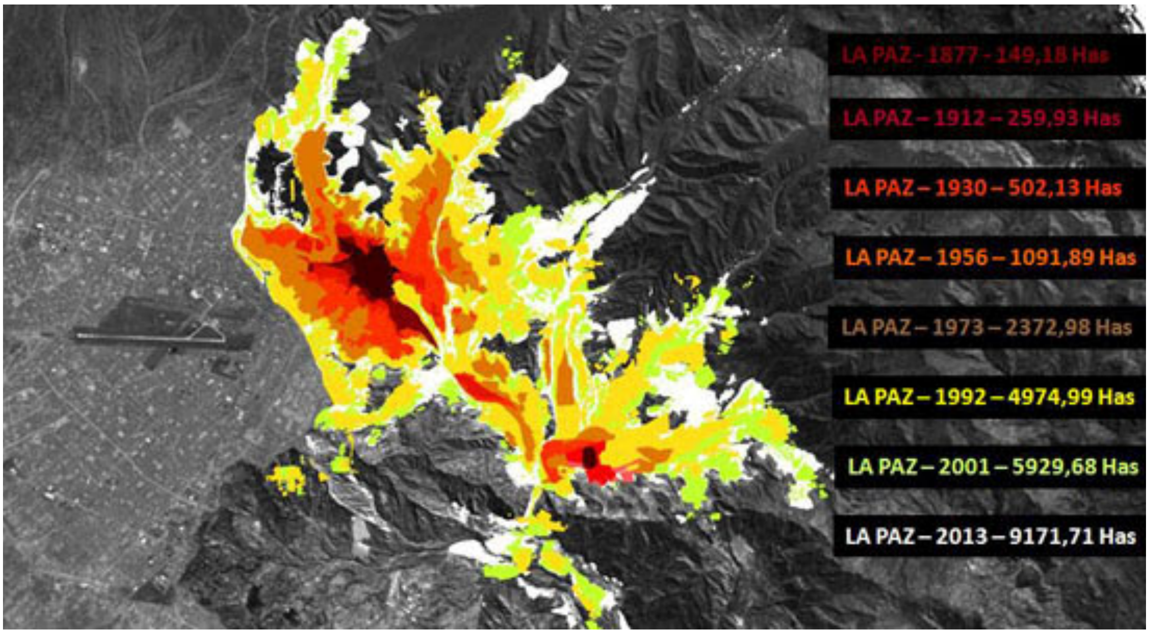
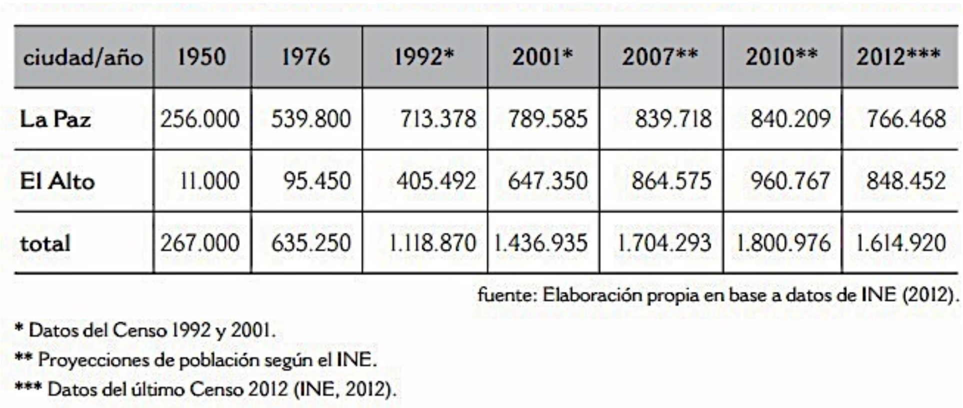


Figure 2-3 Urban growth in La Paz

The inevitable growth of urban agglomeration on mountains, valleys and highlands caused the occupation of hazardous areas threatened by landslides, floods and social conflicts. According to records of older disasters, in 1582 a landslide occurred with torrents of mud in the areas called Kenko and Llojeta, affecting more than 2000 people. In 1837, the sinking of Santa Barbara Neighborhood occurred. In 1959 the city center was flooded (GMLP, 2007).



ciudad/año	1950	1976	1992*	2001*	2007**	2010**	2012***
La Paz	256.000	539.800	713.378	789.585	839.718	840.209	766.468
El Alto	11.000	95.450	405.492	647.350	864.575	960.767	848.452
total	267.000	635.250	1.118.870	1.436.935	1.704.293	1.800.976	1.614.920

fuente: Elaboración propia en base a datos de INE (2012).

* Datos del Censo 1992 y 2001.
** Proyecciones de población según el INE.
*** Datos del último Censo 2012 (INE, 2012).

Table 2-1 Population growth in La Paz

2.6.3 Hazards in La Paz

To identify disasters' location, first the threshold of disaster had to be defined. According to D'Ercole et. al. (2009), there is no reliable inventory of disasters which happened in La Paz. One cause is the distortion of the term "disaster". The threshold of "disaster" in some cases is very low. For example, the collapse of a secondary road did not affect greatly the operation of the district. In other cases a natural phenomenon is described as disaster. For example, a landslide of a large cliff in 1646, which changed the landscape but caused no damage to the population. As a result of an undefined threshold of disaster information on databases can be confusing as a disaster can include anything from an accident to an emergency. For this reason, a selection of disasters that occurred with the greatest impact in the urban agglomeration was performed (Table 2-2).

La Paz is traversed by 250–300 subterranean rivers, making soil extremely unstable, especially during the rainy season from December to March. An earlier geological study estimated that only 19 per cent of the municipal territory was currently fit for construction, and that 46 per cent was too unstable to be converted to support construction (DEGIR, 2012).

fenómeno y lugar	fecha	daños
deslizamiento en Hanko Hanko (Llojeta, Kenko)	2 abr. 1548	destrucción total de la comunidad y 2.000 victimas
deslizamiento Santa Bárbara	1837	destrucción de la iglesia y desecamiento de la laguna Laikakota
deslizamiento en Tembladerani	9 agosto 1873	destrucción de la comunidad del mismo nombre y 32 victimas
torrente de barro en el km 4 de la carretera Panamericana	4 marzo 1947	20 victimas
inundación del río Seco	7 enero 1987	varias viviendas afectadas
derrumbe del cerro San Simón de Alto Villa Copacabana	1 jun. 1995	19 viviendas dañadas y 40 familias afectadas
deslizamiento en Cotahuma	9 abr. 1996	un centenar de viviendas y 13 víctimas
deslizamiento Cuarto Centenario, Germán Jordán	20 abr. 1997	24 viviendas afectadas
deslizamiento en Kupini	1999	varias viviendas dañadas
inundación en el centro y sur de la ciudad de La Paz	19 feb. 2002	10 millones de dólares de daños directos y 68 personas fallecidas
deslizamiento en Alpacoma, Llojeta	4 marzo 2003	200 viviendas dañadas
deslizamiento en Las Lomas	1 agosto 2003	8 viviendas afectadas
deslizamiento en final calle Bolívar	5 abr. 2004	18 viviendas afectadas
deslizamiento Callapa, Valle de las Flores	10 oct. 2009	50 viviendas afectadas
inundación del río Seke	20 enero 2010	159 viviendas afectadas
deslizamiento de Callapa	26 feb. 2011	520 familias afectadas

fuente: GMLP (2005).

Table 2-2 High impact disasters in urban areas in La Paz

The typical solution has been to construct in the remaining spaces, which tend to be in flood-prone, landslide-prone, unstable or wooded areas. It is estimated that 76.85 per cent of the urban area supports ‘spontaneous settlements’, later legalized by the Municipal Authorities, while only 23.15 per cent of urban settlements were legal when first developed (GMLP, 2002a). In the last few decades, the western and northern laderas have been urbanized rapidly and informally, largely by migrants from the neighbouring Altiplano (the great Andean plateau).

Of the 800,000 people living in the La Paz municipality, nearly 500,000 are found in the laderas. The poorest city dwellers live here, mostly in houses of adobe or red brick, generally built without an architect, engineer or technician, and without necessarily respecting rules of sound construction in such a hostile environment (such as extreme slopes with subterranean waters). In this context, it is easy to understand that this population is highly exposed to natural hazards such as landslides, mudslides and floods. This saturated ground is not able to support any weight, and landslides have been reported almost since the foundation of the city in 1548.

In this case study, it is evident that risk tends to be underestimated or denied by the people exposed to it. Even when they are conscious of the risks, they generally do not talk about them nor seek help in addressing them. The irregular expansion due to the uneven topography continued and the street layout could not continue its original design. This is how the appearance of the city developed its current characteristic rendering the generation of continuous straight avenues and streets, more common in other South American cities, impossible. (Candinas,2007).

"The urban area of La Paz city has developed in a narrow valley of La Paz River, with a steep topography, crossed by more than 200 rivers and streams and several sectors of unstable geological conditions.
Moreover, flood trend areas, constructions in high slope hillsides, the alteration of water regimes, the invasion of areas with precarious stability, blocking river streams, and debris and garbage dumping into river channels, are social production factors that increase risk vulnerability city to disasters".
(Ayala, Rodolfo. La nueva vision de la gestion de riesgo local en el municipio de La Paz. Bolivia) (Candinas,2007).

Since the year 2000, there has been a noticeable increase in the frequency of landslides in La Paz, and on 26th February 2011, southern zones were hit by a so-called 'mega-landslide.' This was the worst single landslide disaster experienced in the Bolivia's most populated city in terms of the amount of land, the number of different districts and the amount of people affected. The mega-landslide caused the loss of 223 hectares of land, affecting 1,467 properties and 5,500 people. The economic cost was estimated at approximately US$ 92 million; more than half the annual municipal budget, and the equivalent of nearly all investment in prevention in the previous 10 years (DEGIR, 2012).

More than 400 houses collapsed and 5,000 people were affected in seven districts in the east side of La Paz were the largest damage was sustained from the "mega-landslide" occurring on February 26, 2011. With this disaster, the Special Direction of Integrated Risk Management (DEGIR) of the city government counted at least 50 landslides in four decades.

Figure 2-4 Houses located on steep slopes in La Paz

Figure 2-5 Building built in high risk area in La Paz

Figure 2-6 Structure of an illegal house in La Paz

2.6.4 La Paz Vulnerability

Cities are always exposed to a variety of hazards and this is an essential key to vulnerability. These vulnerabilities are associated with other factors such as rapid urbanization, lack of flat land, limited housing supply, deficiency of policies related to land use, social and economic crisis. This combined with the irregular topography of the mountain system have made La Paz a city under risk (Morales, 1995).

The communities high vulnerability due poverty is linked to a poor resilience capacity. At the same time, there is high exposure to houses built in these areas, which generally use inappropriate construction materials. More than 75% of the buildings are built without municipal permits (Morales, 1995).

Notwithstanding the inherent risk, during the past decades the slopes on the mountain zones of La Paz have been urbanized, either legally or illegally. In the case of legal settlements, the urban landscape and the proximity to centric zones are the main reasons, while in the case of informal settlements the main reasons are availability and low price of land (Morales, 1995). (La Red, 1996).

There are 45000 housing units in La Paz, approximately 32000 housing units are built illegally by low-income groups in poor neighborhoods as a unique solution. These informal settlements are located in slopes or in risk sites because of the initial low land prices or illegal appropriation, and are built through self-help which more often than not leads to further environmental degradation through deforestation, clogging of the natural drainage system with solid wastes and therefore introduce vulnerability (PPR, 2013)

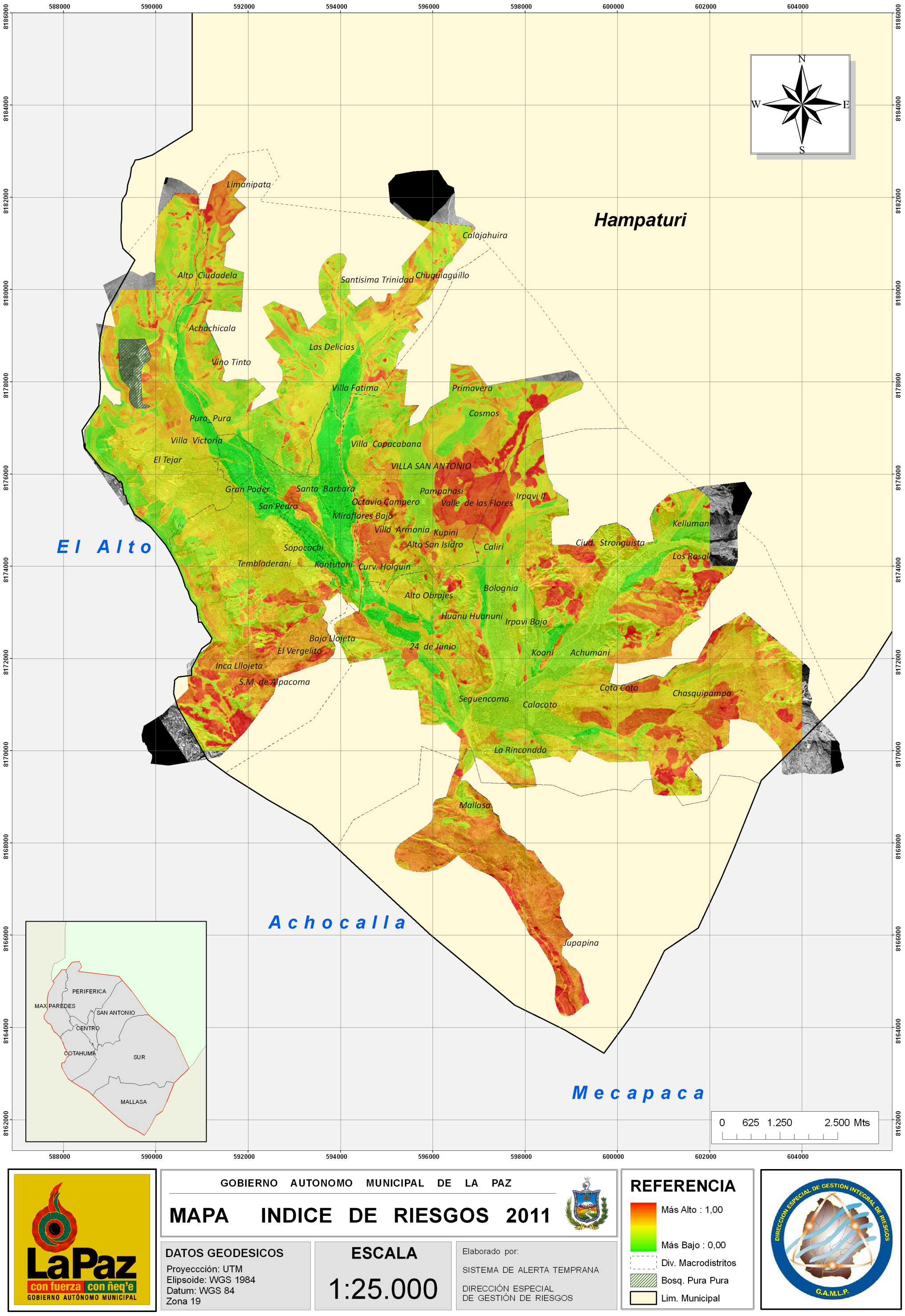


Figure 2-7 Global vulnerability of La Paz population

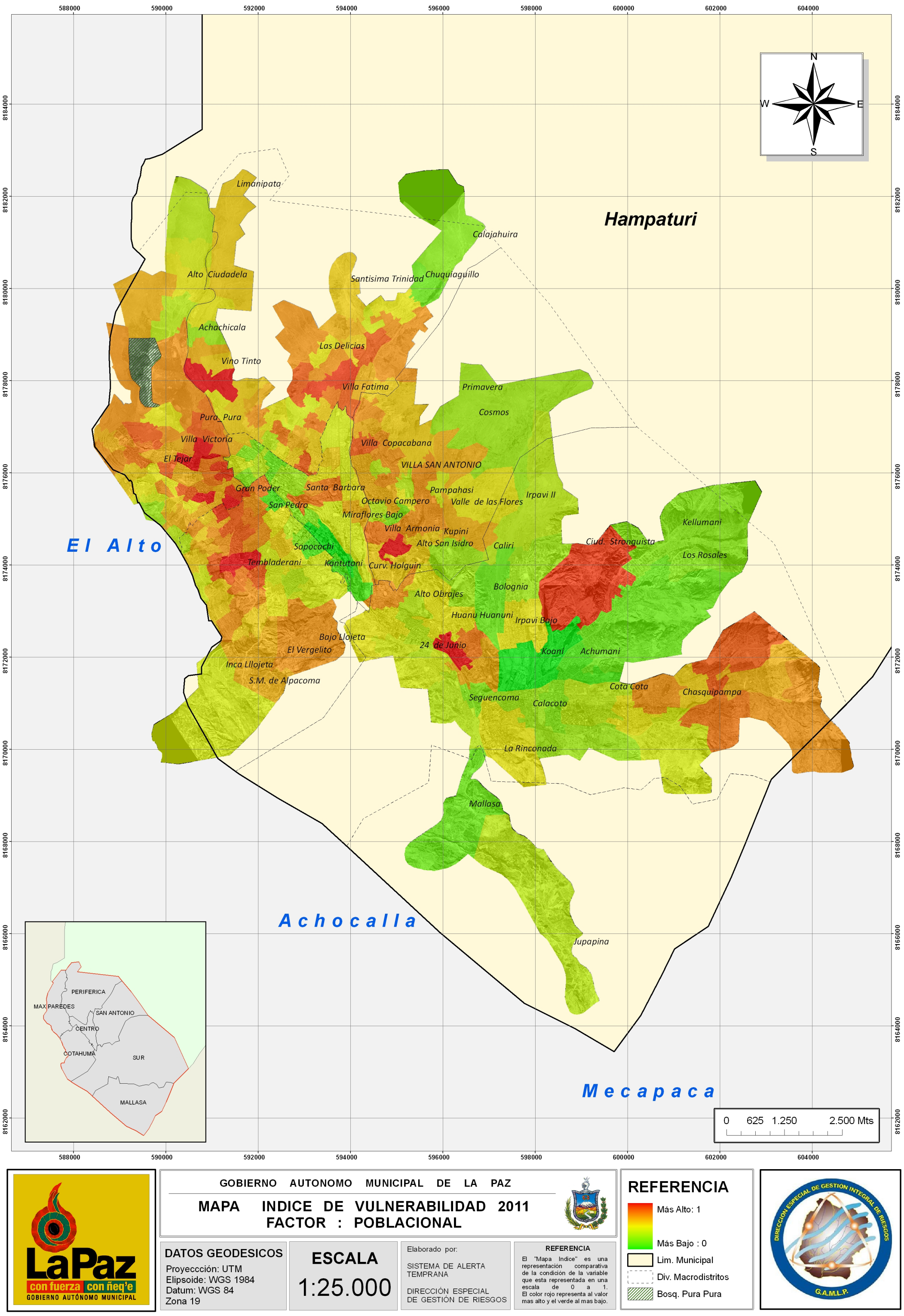


Figure 2-8 La Paz Risk Map

2.7 Case Study Location - Cinco Dedos Neighborhood

The specific location of this case study is the neighborhood called “Cinco Dedos” which is one of the 13 neighborhoods that occupy district 12 of the Macrodistrict Periferica in the northeast part of La Paz City, Bolivia.

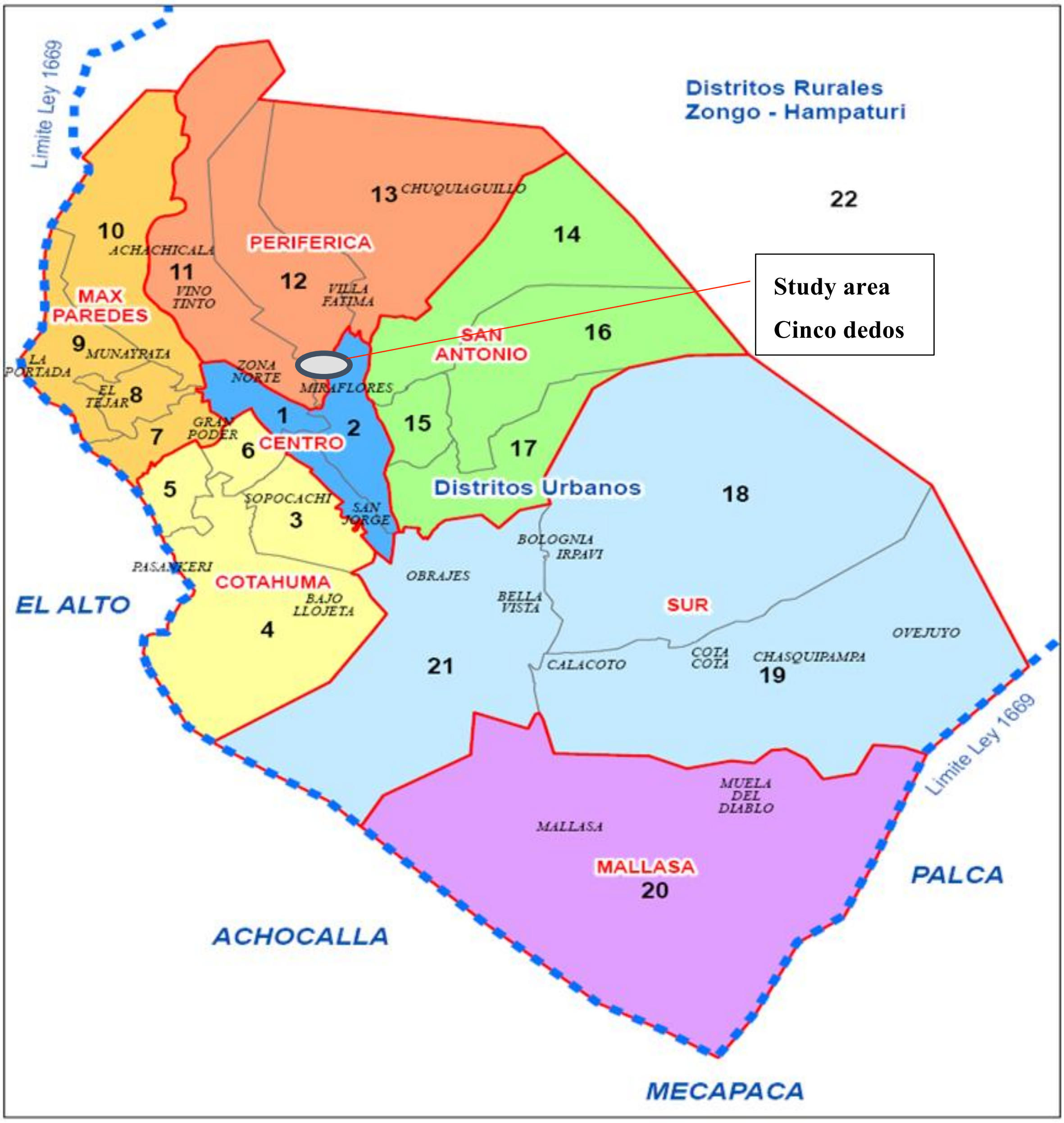


Figure 2-9 Seven macrodistricts of La Paz urban area

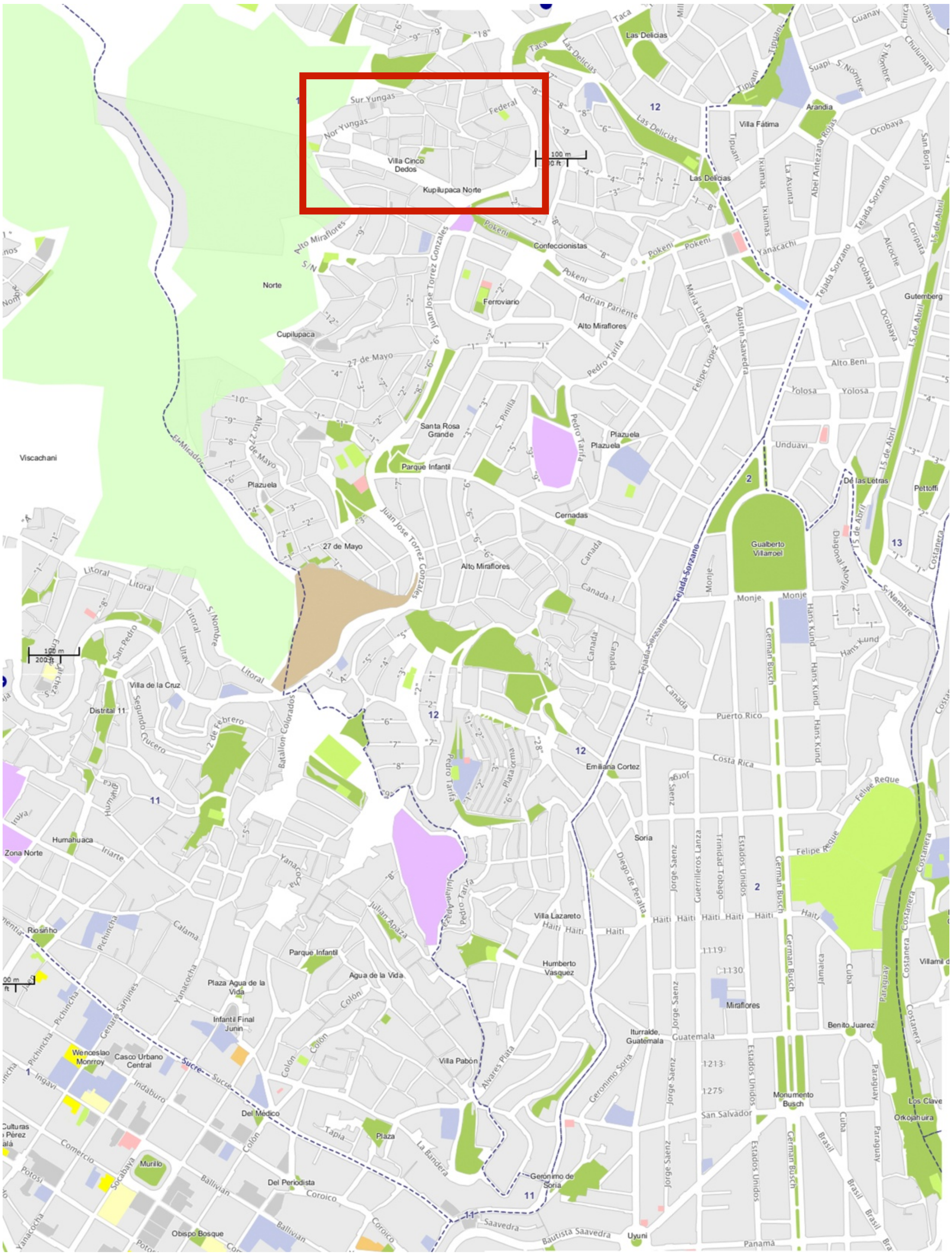


Figure 2-10 Cinco dedos neighborhood Location

200 m.

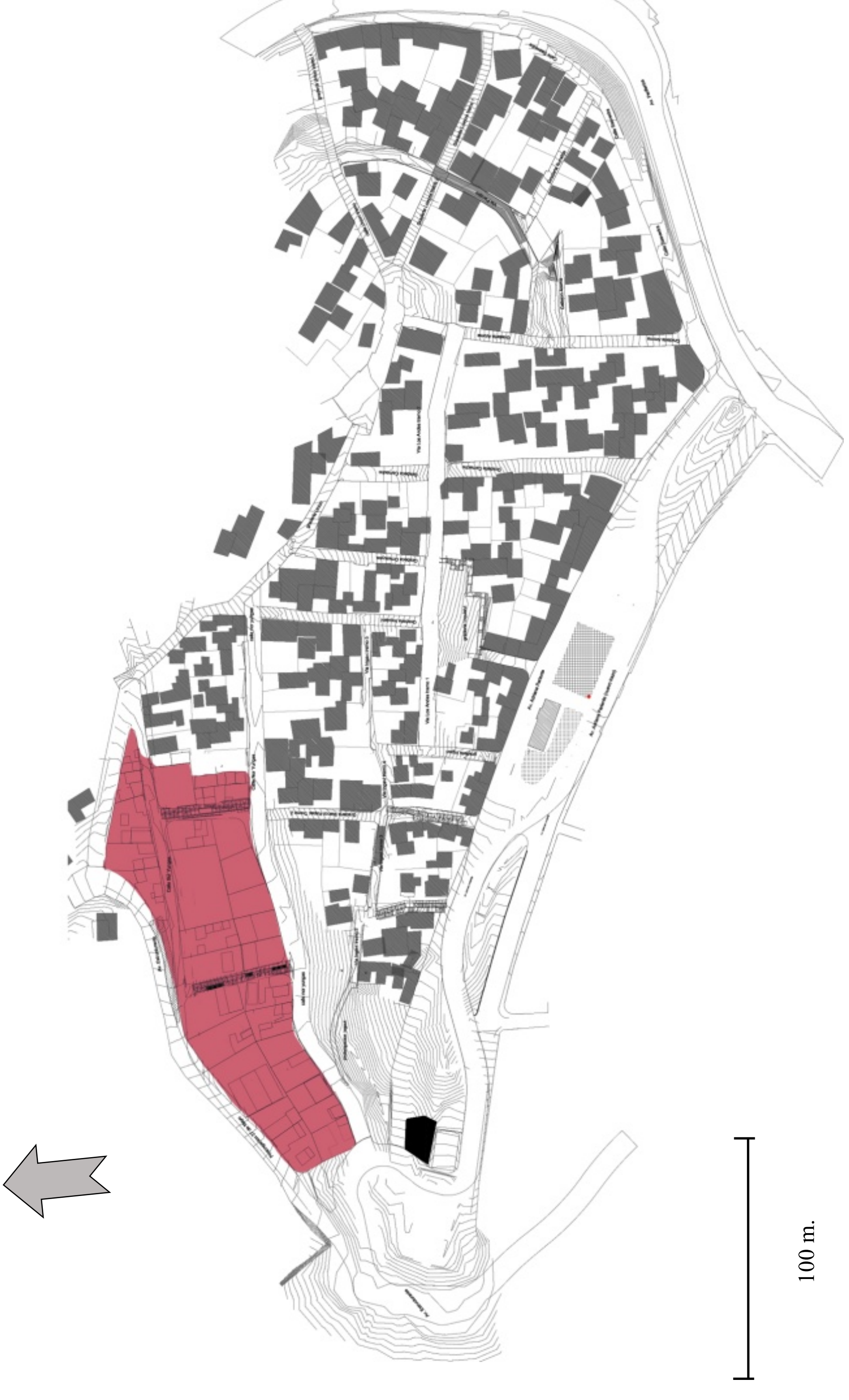


Figure 2-11 Study area in Cinco dedos neighborhood

Distric 12 is one of the three districts of Periferica Municipality sub office. This area consists of 46 neighborhoods, an area of 2601.10 ha, 159,123 inhabitants and a density of 68.90 hab/ha. Many of these residents live in high landslide risk areas (Candinas,2007). Sometimes even at precipice edges or in ravines. The location selected for this work in Cinco dedos neighborhood which is an area at risk in 100% of its extension. As it can be seen in Fig. 2-13, the upper area is part of a steep hill, with the presence of subterranean water filtrations making for instable ground. Most of the houses are made of adobe or red brick, generally built without an architect, engineer or technician, and without necessarily respecting rules of construction in such a hostile environment. In this context, it is easy to understand that this population is highly exposed to natural hazards such as landslides, mudslides and floods.

Figure 2-12 General view of Cinco Dedos neighborhood

Figure 2-13 View from a high point of study area

Figure 2-14 River channel crossing a principal avenue of study area

Figure 2-15 Erosion caused by underground river filtrations

The neighborhood selected for this work has the same geographic characteristics as hundreds of neighborhoods in La Paz City, with the same problems, risks and demographics, which shows that this is not an isolated and unique case to be analyzed. The results and data obtained in this work can be applied in research related to movement of people on steep slopes in urban locations.

2.8 Barrios de verdad program (True neighborhoods)

Mass rural migration in the last two decades, the lack of urban planning and municipal intervention, accompanied by the geological configuration of La Paz City has resulted in precarious human settlements and marginalization, lacking basic services and facilities, with no integration with the rest of the city and weak neighborhood organization.

Therefore, faced with this situation, since 2000, the Municipal Government of La Paz began the Neighborhood Improvement Program to improve infrastructure and community development, improving living conditions and sanitation of La Paz neighborhoods that are in poor conditions.

In the first 5 neighborhoods (phase 0 "zero") they invested US $ 2,911,807 in improving conditions, helping 1,417 settler families from the neighborhoods. This phase was funded by the Inter-American Development Bank IDB (70%) through the National Fund for Regional Development (FNDR) under the supervision of the Ministry of Housing and Basic Services (MVSB). The remaining 30% was funded by the municipal government.

A sudden and massive storm, which occurred on February 19, 2002, highlighted the vulnerability of the city, FNDR MVSB with the approval of the IDB, the municipal government agreed to transfer additional resources for municipality run projects in risk and disasters prevention in La Paz.

With these resources, the municipal government initiated a project focused on the improvement of ten neighborhoods (phase 1) called "emergency projects" located in risk areas.

While this second phase is still continuing, the results achieved so far already show significant changes in the habitability of housing and in the provision of infrastructure for risk mitigation.

Based on this experience, since 2005 the Municipal Government of La Paz created the Barrios de Verdad Program which at that time aimed to equip 100 urban marginal neighborhoods with a new recovered image by 2010.

The mechanism defined for intervention is a public "competition" between neighborhoods not only to prioritize work according to the community demand but also to encourage the participation of all its inhabitants. Furthermore, it allows the municipal government to select from several proposals that have greater impact socially and economically.

No	NEIGHBORHOOD	MACRODOSTRICT	FAMILIES
1	PORTADA TRIANGULAR Y BAJO LIMA	MAX PAREDES	150
2	ALTO SANTIAGO MUNAYPATA	MAX PAREDES	227
3	CUSICANCHA MAX PAREDES	MAX PAREDES	144
4	ALTO CIUDADELA	MAX PAREDES	141
5	EL ROSAL Y MANZANANI	PERIFÉRICA	199
6	KAMIRPATA	PERIFÉRICA	181
7	CUPILUPACA	PERIFÉRICA	325
8	VILLA CINCO DEDOS	PERIFÉRICA	232
9	LOS ROSALES Y LOMAS DE CUPILLANI	SUR	233

Source: GMLP. Barrios de Verdad

Table 2-3 First Barrios de Verdad intervened since 2006

2.8.1 Objectives and components of barrios de verdad

The overall objective of Barrios de Verdad Program is to improve qualitatively the living conditions, safety and sanitation of neighborhoods considered to have low-income population, settled in precarious areas of La Paz city through the realization of integral projects.

The specific objectives are:

- To help improve the quality of life of the population living in extreme poverty conditions in marginal urban areas.
- Integration of road and pedestrian neighborhood internal system into the city road system.
- Legalize and organize the situation of the land.
- Ensure soil stability, preserving the private and public property from risks of landslides, floods, etc.
- Improve the environment, recycling and cleaning system of neighborhoods.
- Incentive to the processes of community organization
- Generate the inhabitants sense of ownership over their physical environment.

The program includes an intervention strategy grouped into two components: physical component and community development component and regularization of property ownership.

the physical component intervenes on an integral road system, basic services, risk control system, community infrastructure system, environmental system and street furniture.

The Community Development and Regularization component has four lines of action aimed at promoting social support, protecting the environment, ensuring the sustainability of the project and formalize the status of the land.

2.8.2 Stair construction for Real Neighborhoods Program

Cinco Dedos is not a special case of a neighborhood with hundreds of stairs as primary pedestrian ways and streets (Fig. 2). This is one of the until now 80 neighborhoods remodeled by “Programa Barrios de Verdad” (Spanish for Real Neighborhoods Program) which not only constructs stairs in inaccessible areas of the steep neighborhoods, but also provides parks, community housing, traffic access, and sport recreational areas to people who live in the Laderas of La Paz. According to information received from the Government office in charge of Macro District Periferica, more than a hundred Barrios de Verdad are projected for the following years, all of them present the same geographic characteristics. It means that stairs like the ones we are using for our research will be present in the 20 projects in execution this year and 50 more projected for year 2016 if the necessary funds are obtained from the different non-governmental organizations. Since the design will be implemented in areas which share the same language and configuration of steep streets, the approach of the evacuation program will be the same for all neighborhoods.

In La Paz, residents, community leaders and city planners tend to underestimate or deny risk, which weakens the creation of an effective risk management. Physical and socio-ecological exposure, incapacities to prevent, technical, political, socio-economic and cultural weaknesses, the overall vulnerability is a combination of some or all of these aspects (Nathan, 2008) These adverse aspects make La Paz a proper scenario to apply this work. Showing the community a graphic example of what could happen to their neighborhood if a disaster happened could create a community consciousness about the need for disaster education.

CHAPTER 3: DATA COMPILATION AND INFORMATON PROCESS.

La Paz City Communities Perception and abilities related To Landslides Disasters Management

3.1 Data collection in order to identify community abilities for landslide risk management

A field research in La Paz was made to study the landslide risk management system at the community level through surveys developed to qualify a representative part of La Paz City population.

This section presents the data analysis to integrate the information collected into a scenario where landslide risk management practices in La Paz can find an effective pre- disaster strategy to be used in the short term.

This case- study analysis was made in order to measure and test the level of knowledge, perception and the behavior communities have related to disasters
This information will lead to the creation of an strategy that the communities could accept and apply so the effects of a landslide will be reduced.

The method used for this section was based in Cruz (2010) work. Since the location where this survey was developed and implemented presents the similar geographic, social and cultural characteristics as La Paz.

3.2.1 The sample

70 communities or neighborhoods from 9 Administrative Zones of La Paz City were selected as the sample framework for this investigation.

The criteria for this selection was based on neighborhoods that have both 1) been located in a moderate to high risk area 2) registered landslide events in the past 5 years.

An interview with the president or leader of each of the neighborhoods within the study area was held.

The leaders of 70 neighborhoods - since they are representing their communities - should comply with some requirements in order to obtain the most accurate information possible: They were elected democratically and they must live in the neighborhood.

The age of the people surveyed were from 45 to 70 years old. At that time they had been living in their neighborhoods from 15 to 35 years and they had been leaders from 1 to 4 years.

In the case where the president was not able to participate, the vice-president or another member of the neighborhood commission was delegated to answer the survey. Annex 1 presents the list of neighborhoods according to each administrative zone.

Figure 3-1 shows a map of La Paz City in which the first selection criteria (geomorphological risk) is represented by colored areas and the second criteria (past occurrence of a landslide events) is represented by red dots. Neighborhoods that experienced both of these criteria were chosen to be part of the study.

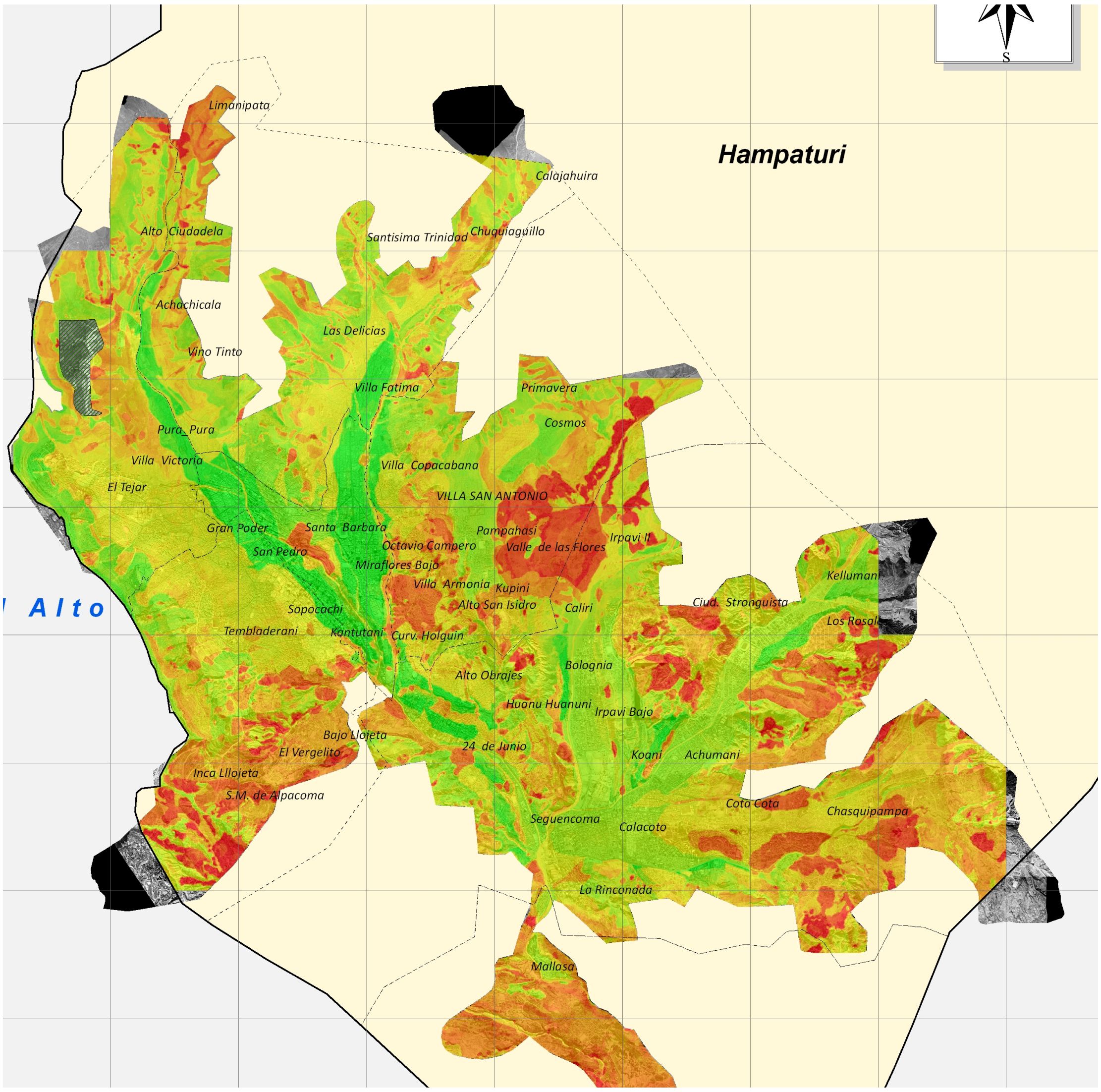
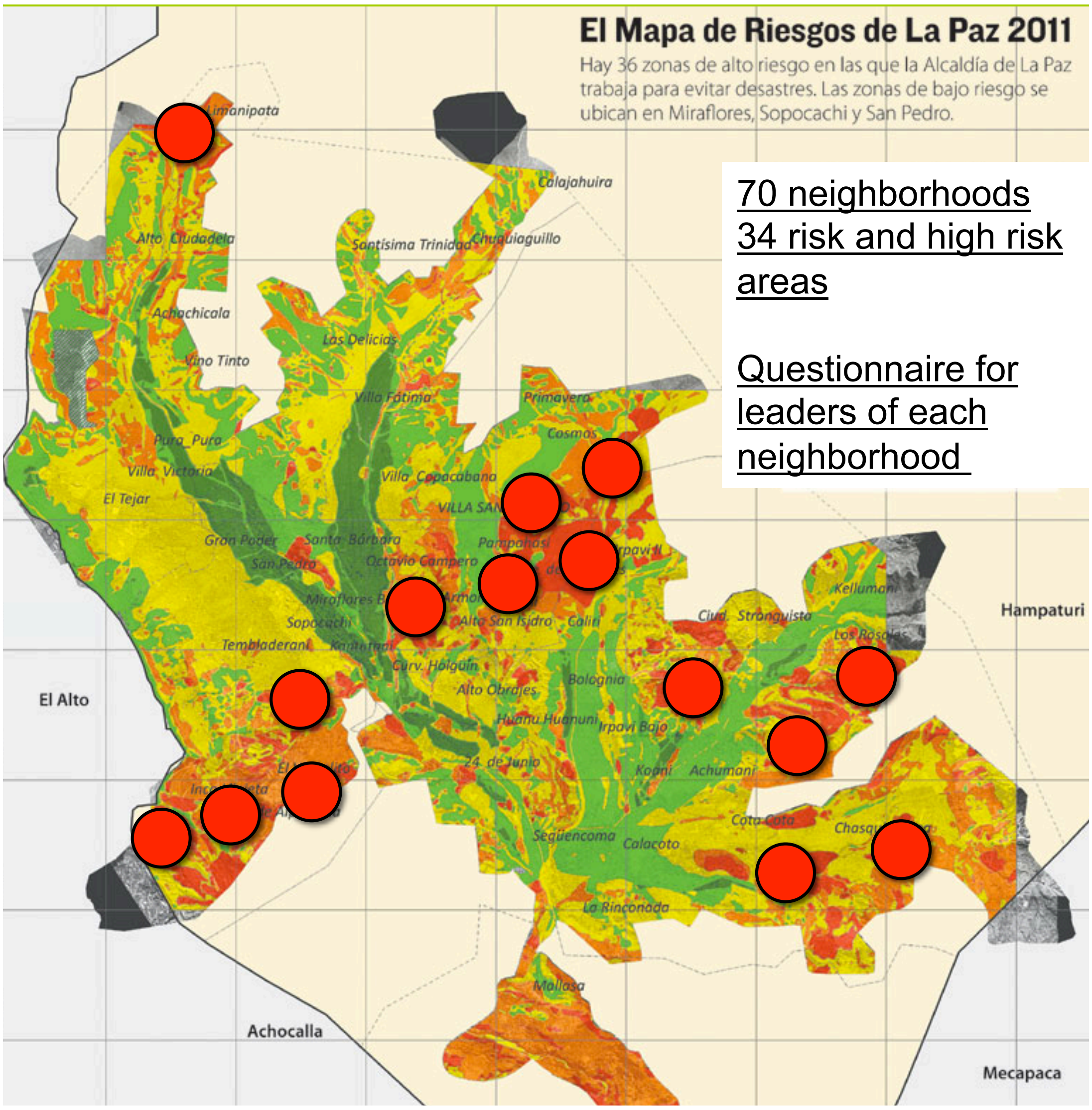


Figure 3-1a Neighborhoods selected for the research (Risk map)



<u>70 neighborhoods</u>
<u>34 risk and high risk areas</u>

<u>Questionnaire for leaders of each neighborhood</u>

Figure 3-1b Neighborhoods selected for the research (Areas where landslides happened in the last 5 years)

3.2.2 Surveys

The surveys were developed for the 70 community leaders. 57 questions in total were asked evaluating the landslide risk management performance in each neighborhood as well as the community abilities in place to cope with landslides. The survey questions are presented in Annex 2.

3.2.3 Surveys distribution

The gatherings with the representatives of each neighborhood and the application of the surveys lasted four weeks. Three teams of interviewers carried out the surveys. The teams received training in order to clearly understand all of the questions of the survey. Once the teams were ready, each of the 70 community leaders were contacted to arrange a date to visit the neighborhood and apply the survey. After the surveys were finalized, they were handed in and the information was reviewed together with the interviewers.

The rate of data collected was 100% since we were able to contact and talk with all the leaders of the 70 neighborhoods selected.

Legal or illegal, all the neighborhoods (100%) surveyed are organized by a Community Committee. Formed of a president, vice-president, treasurer and secretary they are in charge of arranging and negotiating works needed for the neighborhood, the process of regularization, as well as organizing the community and informing them about their activities.

3.2.4 Data processing and results

Once the surveys were finished and reviewed, each of the questions were codified and digitalized to create a database.

From the information collected, a quantified analysis of how the community perceives and manages landslide risk and the level of resilience was made, as well as as assessment of the community's attitude and abilities in place in regards to landslide risk management.

The results generated recommendations in regards to the institutional and community capabilities that will increase the likelihood of improving the response of a community to landslide disasters in La Paz City.

3.3 Landslide risk management at community level

Risk management experts acknowledge that an effective way to reduce vulnerability in a society is to involve the community since unsustainable development will always produce risk (Cruz, 2010).

This thesis section analyzes the abilities of communities located in landslide prone-areas and the way their inhabitants perceive the hazards and their attitude towards them.

The data presented next, surveys applied in 70 neighborhoods of La Paz provides a general description of the vulnerability of the neighborhoods and, if they exist, the basic community landslide risk management systems.

Figure 3-2 View of Cinco dedos neighborhood, one of the areas surveyed for this study

3.3.1 Political and social vulnerability of the neighborhoods

In La Paz urban area, one of the main reasons for the increase of risk of landslides and the vulnerability of the population is the illegal settlement in slope areas.

Of the 70 neighborhoods included in this analysis, 87% of them were not legal neighborhoods, and only 10% were in process of regularization.

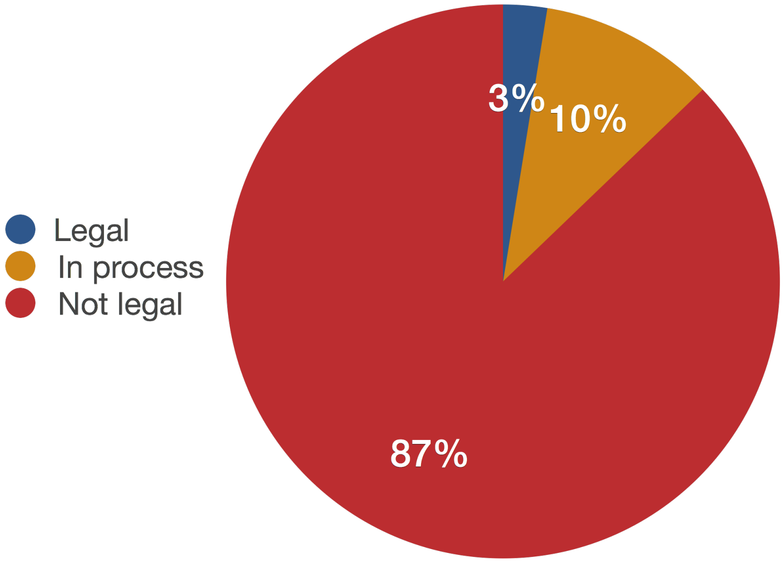


Figure 3-3 Status of legalization of 70 neighborhoods settled on high risk areas in La Paz

Reasons for not being legal neighborhoods include: they are settled in high-risk areas that are illegal for housing construction as declared by the government. Problems in the legal process and lack of documents that prove they are legitimate properties, no interest in the community in becoming regular neighborhoods and lack of organization among the members of the community.

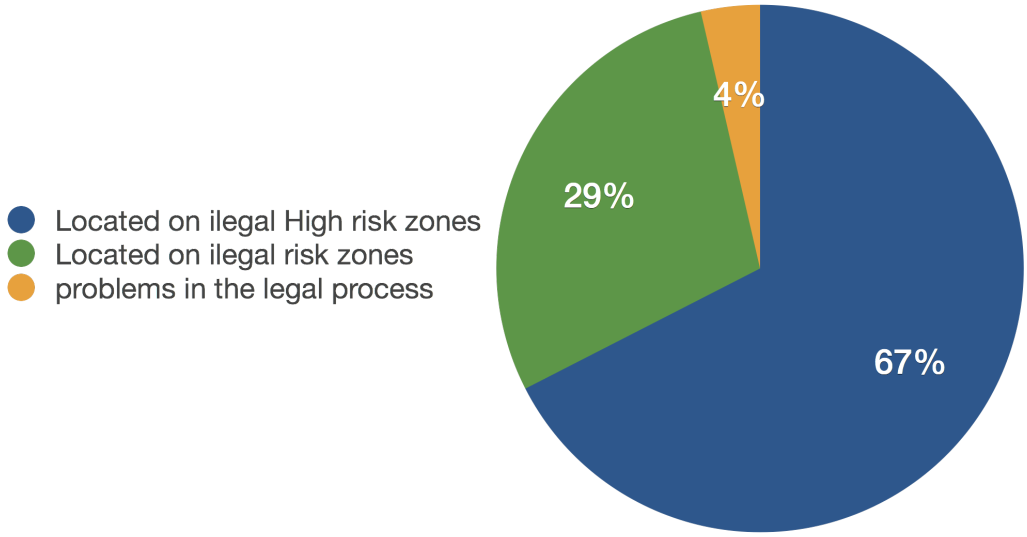


Figure 3-4 Principal reasons why the neighborhoods are not legal

Basic services

One critical characteristic of these neighborhoods that increases vulnerability is the unbalanced basic services provision.

The results of the surveys showed that these neighborhoods are in general provided with electricity and potable water if the community asks for the service. However, of the 70 neighborhood where 60% of them have potable water system, the provided sewer system is only present in 30% of the neighborhoods.

Half of the houses dispose wastewater into riverbeds or into the soil, provoking infiltrations.

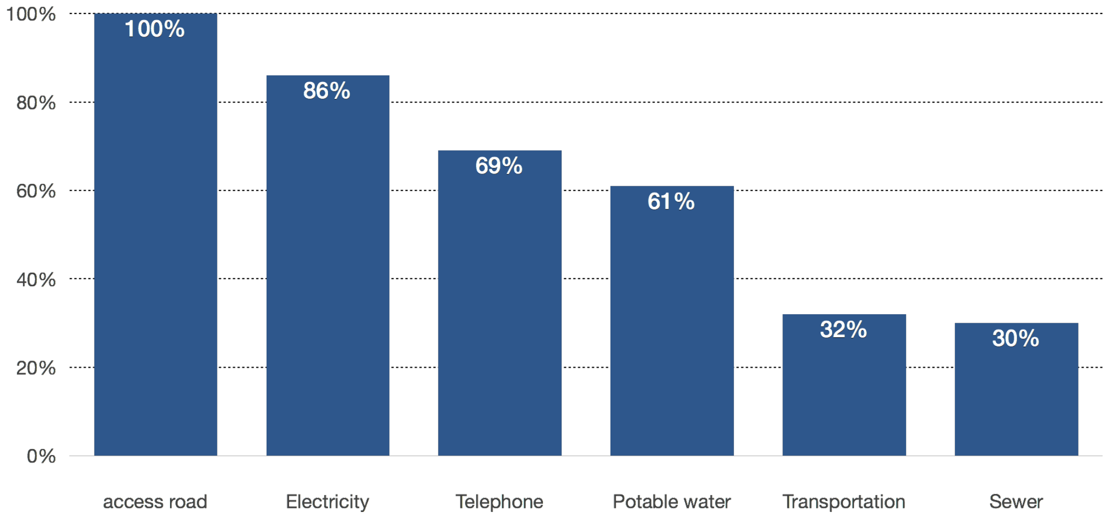


Figure 3-5 Percentage of basic service coverage

3.4 Community risk and vulnerability perception

More than 60% of the community leaders identified houses built on slopes and landslide prone-areas as the most relevant risk zones in their neighborhoods, followed by traffic accidents and crime and violence. More community leaders identified safe areas such as community centers and police units.

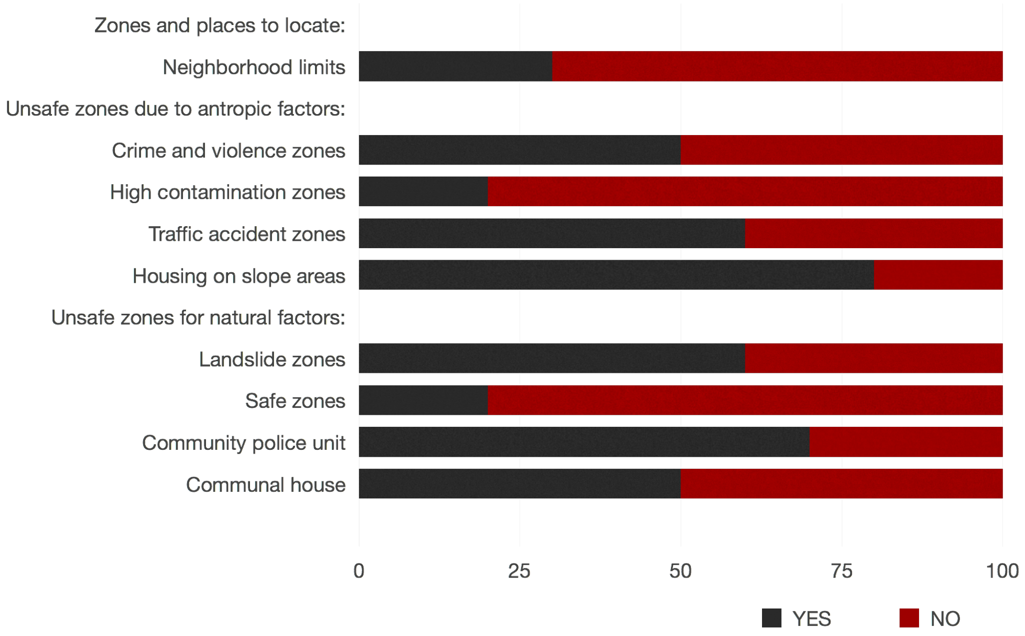


Figure 3-6 Identification of risk and safe areas

When the leaders were asked about which natural event was the most frequent in their neighborhoods, most of the leaders answered none (69%), followed by landslides events (30%) and floods (6%).

In each the 70 neighborhoods selected for this data collection, at least one landslide was reported in the last 5 years. This information demonstrates that people living in these areas have a low perception of landslide risk. A reason could be that they do not have access to information, the information is not is insufficient or they just deny the risk in their neighborhood.

81% of the community leaders think that the communities feel safe in regards to landslide events. From this percentage 87% consider their neighborhoods as a safe zone without landslide risk and only a few feel they are prepared to act in the case of a landslide (23%). On the other hand, 19% don’t feel safe because they recognize that they are located in a risk zone and that their constructions are not properly made.

Leaders who do not feel safe, think that the most important actions they need to do to improve this situation are increase awareness programs and plans (67%) as well as implement the development of preventive structural works (39%). Other leaders believe that communication between the community members and the government is needed (25%) and that more people need to learn mitigation, prevention and preparedness in a easy way(10%). few believe that the government is the only responsible to improve their safety situation (8%) and even less consider it necessary to move to another place to live (2%) as long as the government provides them beter conditions than the one they are living now.

3.4.1 Level of vulnerability

The leaders were asked to give their vision about the perception of the population related to vulnerability on a level assigned to each of the neighborhoods that varied from low to medium to high. The majority of the neighborhoods (42%) answered that they live in a medium vulnerability, followed by a low level of vulnerability area (35%). 23% of the neighborhoods had a high level of vulnerability perception.

3.5 Community landslide risk management response

3.5.1 Information, education and training

The perception a community has about risk and vulnerability, as well as landslide preparedness is a result of their access to information, education, and awareness raising campaigns (Cruz, 2010). 67% of the community leaders mentioned that the people living in their neighborhoods have not heard about hazards and risks that affect them and this is reflected in the low level of risk awareness. The other leaders believe that their neighborhoods have some knowledge about landslides and probably also about disasters in general (29%). Some leaders knew that someone in the neighborhood knows about landslides risk and prevention (4%).

According to the people interviewed, the knowledge neighbors have has been obtained mostly from their own experience and in a lesser degree from education and awareness-raising campaigns and workshops held by the government bodies, the community leaders or from the mass media.

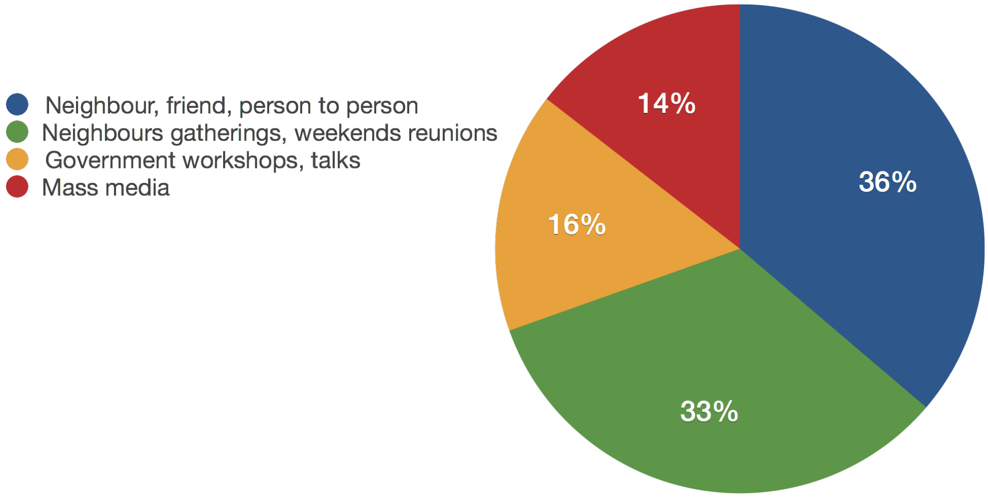


Figure 3-7 People source about hazards and risks that affect them

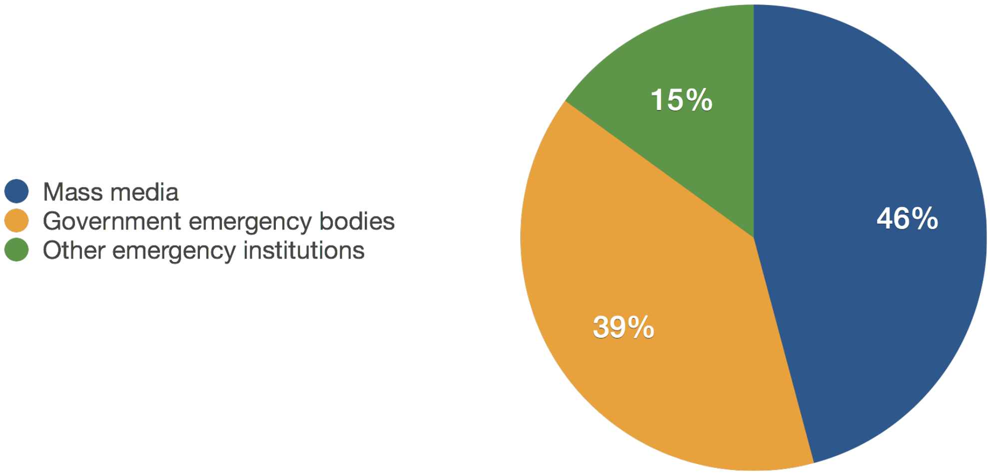


Figure 3-8 Neighborhoods principal external information sources about hazards and risks in the last 2 years in illegal neighborhoods

In regards to awareness-raising talks and workshops, 60% of the people interviewed stated that the members of the community have received talks about hazards and risk in the last two years, of which the majority have been annually (77%) and more than once in a year (23%).

The principal districts are identified as the ones that received the talks with the main topic being natural disaster prevention and security. In the neighborhoods where these talks were given, 60% of the leaders interviewed think that only a minority of the community participate, 28% think that only a small part of the community participate, 9% think that a big part of the community participate, and 3% think that the entire community participates.

3.5.2 Prevention and mitigation

The community leaders answered that a big percentage of the population (33%) doesn't know about land use occupation regulations and construction codes. The rest of the population knows them, but only 4% of them comply with those regulations.

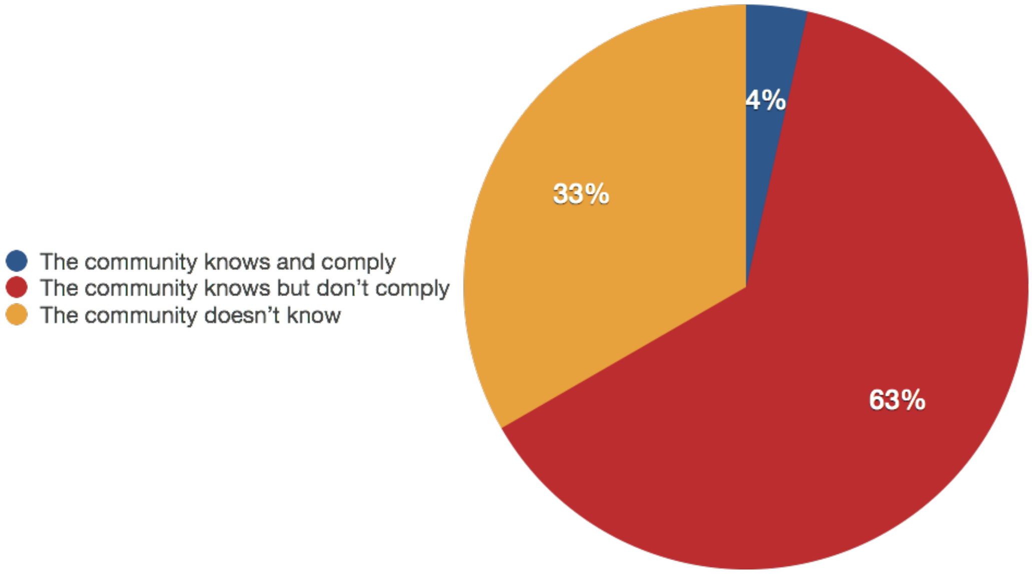


Figure 3-9 Community knowledge and compliance of land use regulations

Even though most of them know about the danger, when they build their houses, only 40% of the population considers the risks they are exposed to. The main reasons (combined in more than one reason per answer) why the new settlement population does not comply to the regulations or consider risk when they settle on these areas are: lack of knowledge, information and interest (65%); they believe that no disaster will ever happen or affect them (47%); are irregular settlements (29%) and the lack of control mechanisms (15%).

Some community leaders recognize that development and structural work and basic services provided by the government have improved their neighborhoods, and made them safer preventing landslides and floods (43%). Nevertheless, a high percentage also thinks that there are no achievements that can be identified (40%). A smaller percentage of community leaders also think that most of the people do not consider any development in their neighborhoods because they do not see themselves personally affected by the development.

3.5.3 Emergency preparedness

Most of the community leaders believe that the members of the community don't know what to do in the case of a landslide. People who expressed that they know what to do, they just said they would basically go to a safer place. Only 20% of the leaders interviewed mentioned that there is a warning system or a community alarm, however, this community alarm is mainly used for crime and violence, followed by any type of emergency (12%). The interviews showed that they have no alarms used for natural events.

In the same line of emergency preparedness, drills were never implemented in the neighborhoods.

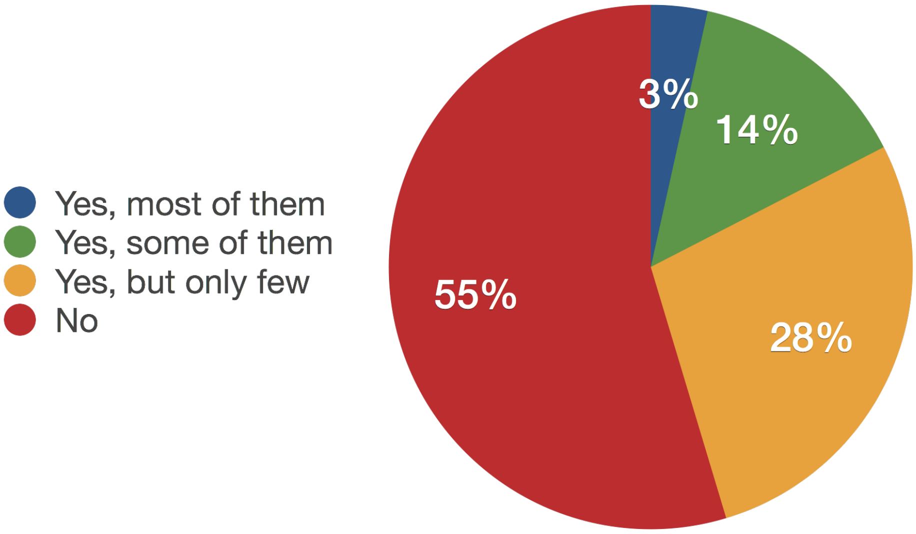


Figure 3-10 People who consider the community members are prepared and know what to do in case of a landslide

3.5.4 Recovery and reconstruction

Community leaders informed that after a natural event like landslides and floods on a small scale, the affected families did not receive any support to recover in more than 40% of the cases. Around 50% mentioned that they have not experienced any natural disaster event. The rest 10% answered that the families affected by larger scale disasters received physical, social or economic support. None of the neighborhood leaders reported a family from their communities accepted to be relocated to a safer place.

3.6 Community abilities related to landslide risk management

3.6.1 A top-down or bottom up approach

La Paz government offices and bodies are responsible for the disaster risk management of all the communities with a top-down approach in the application of programs and strategies. 45% of the interviewees believe that these offices and bodies are present in their neighborhoods. Out of that percentage, the community leaders recognized that these bodies work either implementing structural works for the neighborhood improvement (60%), also providing talks and training programs related with security (50%) or supporting them with the regularization process (30%).

However 55% of the people consider that government offices and bodies don't do anything for the neighborhoods.

When the leaders were asked if they believe that the community and their neighborhoods are considered by the government in matters related to the development of the city, only 23% answered positively. According to their answers, their neighborhoods are considered in the development of the city because they have support, training courses, workshops and advice for community development as well as works for the neighborhood. However, 77% don't feel that they are included in this development of the city, giving the following reasons: lack of work in the neighborhood, the increase of irregular settlement, little organization between them in the neighborhood and absence of communication.

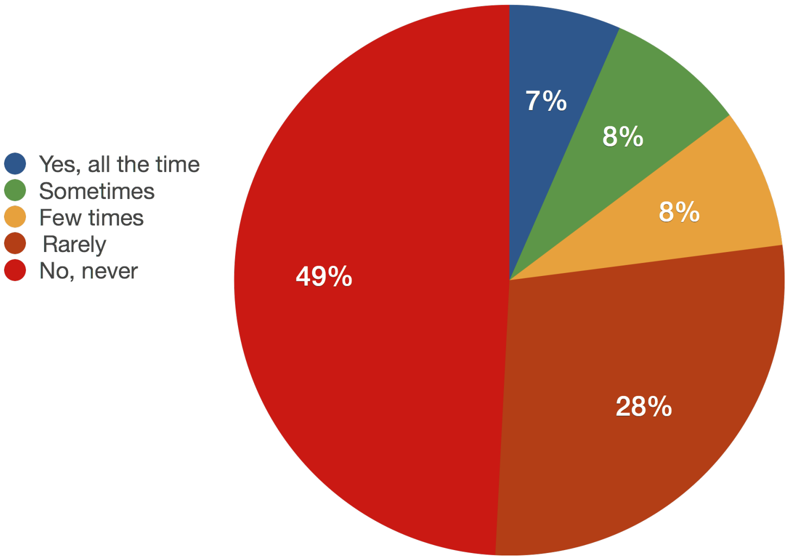


Figure 3-11 People who consider that the neighborhood has been taken into account by the municipality in themes related with the city development

There is a debate about the more effective approach for a landslide risk management. The top-down and bottom-up approaches discuss the relevance and empowerment of the community participation in the bottom-us approach, instead of the traditional and highly controlled top-down approach. It is important to acknowledge that landslide risk management executes and plans different events, through a layered and hierarchical system and according to King (2008) such management may not necessarily follow an opposite direction to be effective, but all levels of the community should be integrated and engaged so they can be part in developing a customized risk management (King, 2008). This is why community abilities are a key aspect to be considered.

3.6.2 Empowering communities

The communities studied are in general aware that they live in a landslide prone area. They know that the combination of them living in high slopes, heavy rain, deforestation and the absence of sewer systems will have serious consequences. But in spite of this, the community members who were part of this study put less importance on landslide risk and other natural hazards, as they were more concerned about their everyday livelihood which was seen as a more immediate threat to their lives rather than relatively infrequent landslide events. More than half of the population does not recognize landslide risk as a serious threat.

Most of La Paz population living in risk prone neighborhoods considers landslides to be beyond their control and rely mainly on the local government to provide external control and to take some actions to lessen the impact of the landslide events if it should occur. Social and economic influences have serious effects on the population willingness to accept risk. Moreover, there are other social problems communities are distracted by, such as crime and violence, which was found to be one of the most important concerns of the community. King (2008) argues that landslide risk management is a political process in competition with other priorities and issues. Thus, strengthening community involvement is strongly needed in risk management.

3.7 Communication and coordination

One of the main reasons why community empowerment has not been achieved is due to poor communication and coordination between the community itself and the government bodies related to risk management. The lack of communication is a limitation and also a source of frustration and unaccountability. Well equipped communities that have been provided with the necessary tools and strategies for landslide risk management can significantly contribute to government efforts to implement landslide risk management policies and therefore also become active participants. In order for this to be accomplished, good coordination and communication between the neighborhoods, the government and other stakeholders involved is required.

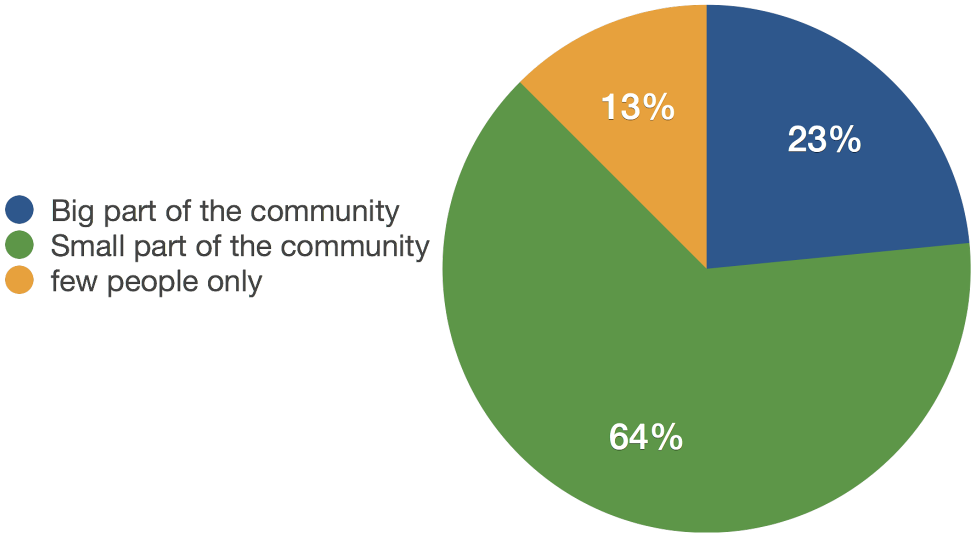


Figure 3-12 Part of the community living in high risk illegal neighborhoods who participate in talks about hazards and risk

Almost half of the community leaders believe there is no coordination at all between the neighborhoods and the La Paz government; 36% of people in communities think there is some coordination but they do not trust the approach government uses; 13% believe there is good coordination since they found some solutions through government legal procedures, and 7% not only recognize good coordination and dialogue with the municipal actors, but also cooperation from all the community.

In order to accomplish disaster risk co-management between community and government bodies, effective coordination and cooperation is needed. Any obstacle in this process will only decrease the opportunities of having resilient communities.

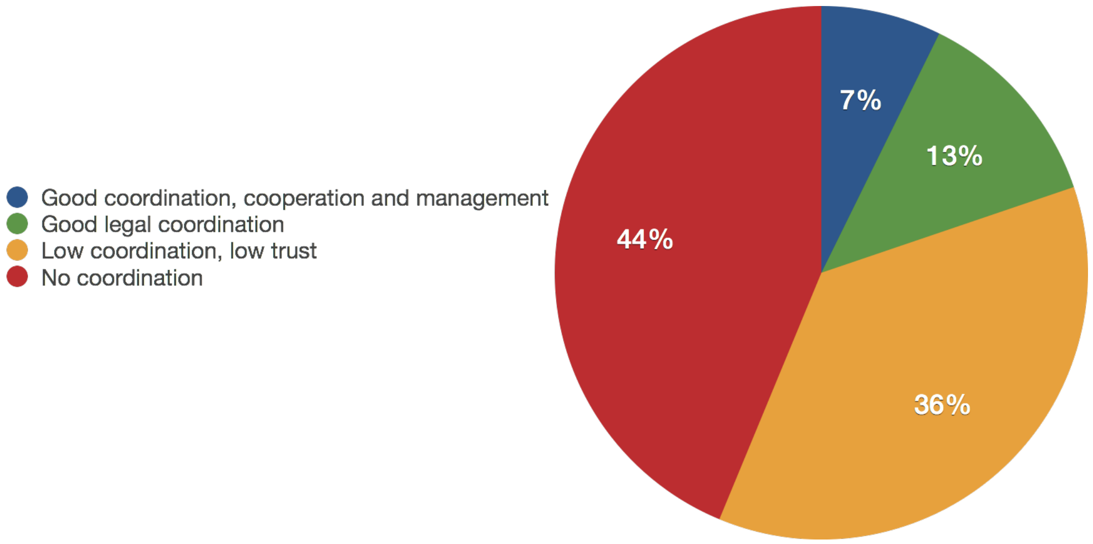


Figure 3-13 Communication and coordination between the neighborhoods and the Municipality

3.8 School Questionnaires and Class Practices

As mentioned before, an important aspect of natural disasters prevention is Natural Disasters Education. If this is applied from an early age, it will have successful and positive results, especially when it is aimed to reduce risks and their consequences. A good platform to implement natural disasters education is in the formal aspect of education, precisely, because subjects in elementary and secondary schools, including geography as an interdisciplinary science provide opportunities for understanding all aspects of natural disasters and thus play an important role in prevention. (Panic, 2012)

3.8.1 Questionnaires for student/participants

A survey was conducted with school-aged children of which the purpose was to check their knowledge and perception about landslide hazard and response to a landslide disaster.

The selected school was U.E. Adolfo costa Du Rels in Periferica district of La Paz. The research was conducted through a survey with elementary school students. The questions were related to knowledge about landslides, knowledge about what to do during a landslide, if they would like to know more about disasters and what to do in case a landslide happens, and an important point, if they would be willing to teach and transmit what they learn to their families.

The results showed that only 10% of students responded correctly about what to do in a case of a landslide, 90% of students are not aware that their answers were wrong about what to do during the landslide, the subject left a significant impression on the 80% of the students and almost all of them expressed an interest in training on appropriate behavior during disasters and also teaching what they learn to their families.

30 students aged 11-13 years were surveyed, from 4th grade of secondary school. They filled out the questionnaires at school, during classes. The questionnaire covered 30 questions. Questions are in Annex 3.

Based on the information obtained, the results are:

- Students' knowledge about disasters is incomplete and inadequate.

- Reaction students would have at the time of a disaster was inadequate.

- Students are not aware that their reaction at the time of the disaster would be incorrect.

- Students need training in order to behave correctly before, during and after an landslide.

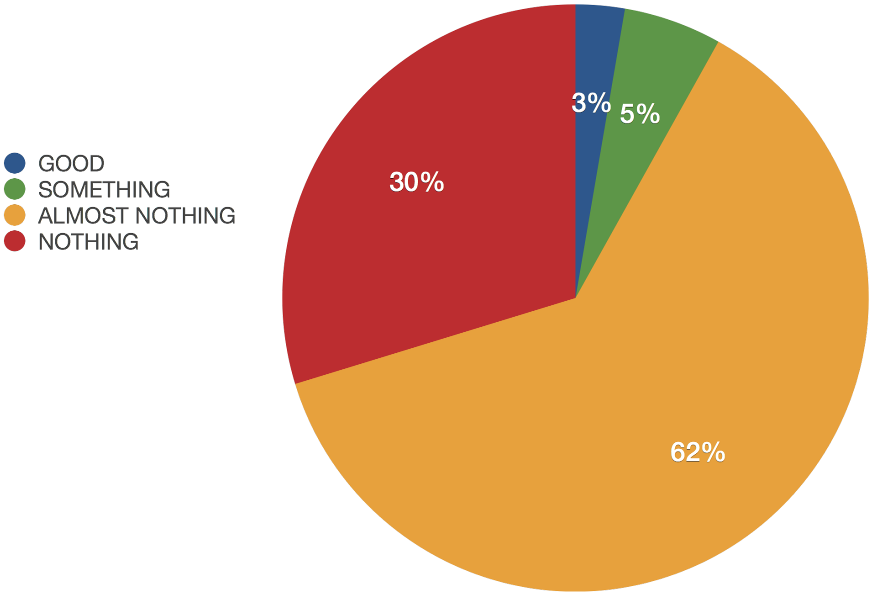


Figure 3-14 Students' knowledge about disasters

In one of the questions, students were asked what their reaction would be during a landslide. About 60% of all participants wrote they would stay where they would be at that moment, and about 40% of participants wrote " run out immediately".

Since a landslide can occur, for instance late at night, when the students are at their homes, with their families, it is clear that they do not have to make decisions independently. But, this situation indicates that adults are not familiar with the proper way of reacting in these situations either. They also had no recollection of landslides that happened, nor in the area they live or in other areas in La Paz.

When they were asked what they think about knowledge and training on proper behavior during natural disasters that could be implemented as part of the school program the most common attitudes for students of both gender were that they need to learn how to behave during and after a landslide. The important data obtained is that students know that there are certain rules and procedures to follow in emergency situations, but they are not familiar with them and they realized that they should be, and therefore, this information should be included somehow in the content of education programs.

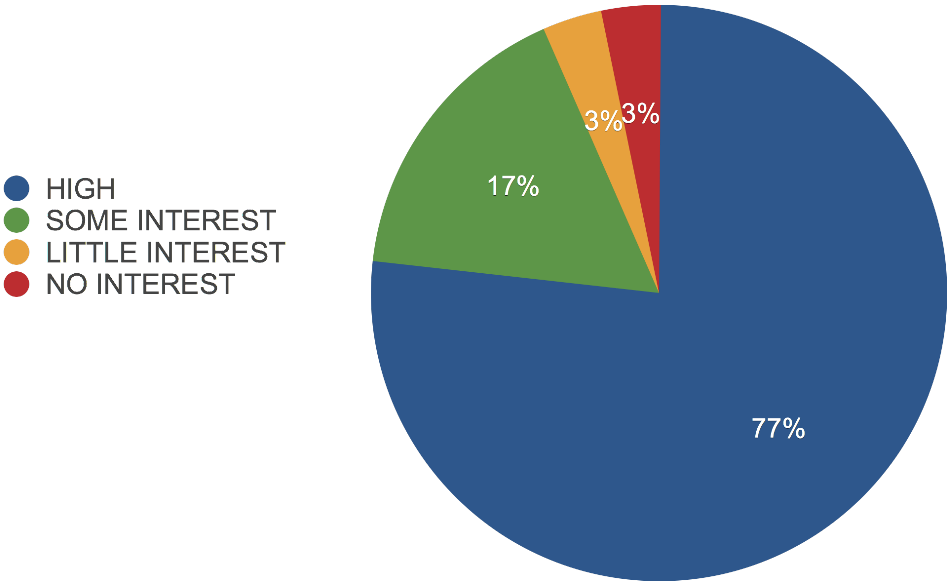


Figure 3-15 Students willing to learn about disasters

About 80% of participants said that after the survey, they are now more interested in natural disasters and that they would like to read about this topic on the Internet or in books; only 5% did not express the same interest.

More than 80% of the students showed interest in transmitting the knowledge about disasters they could learn at school to their families. This could be an important asset since the information and knowledge would be taught to the whole family, and that means that the knowledge would reach the community.

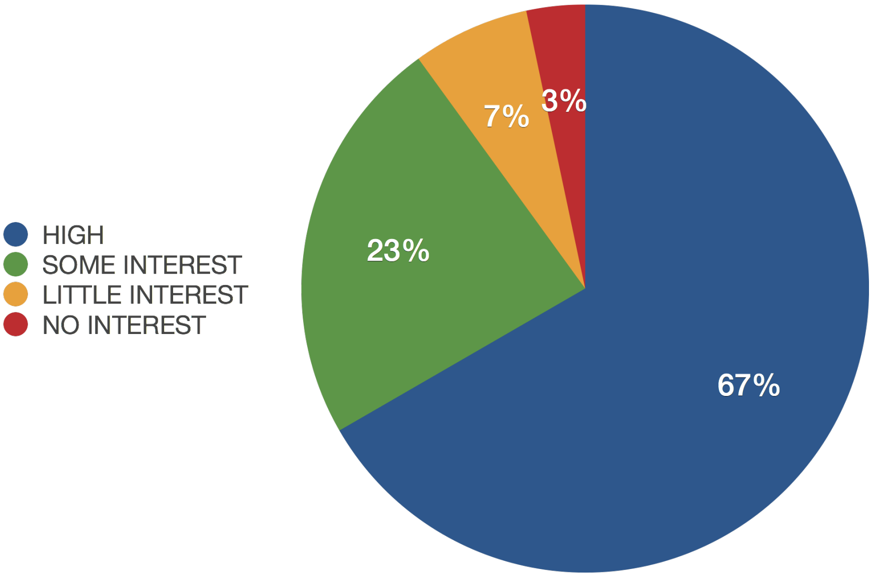


Figure 3-16 Students willing to teach about disasters

3.8.2 Disasters perceptions – Student Group A and B

Another survey was held for older students in the same school. Two groups were selected, one of them (Group A), 16 students in 6th grade (16-17 years old) with previous disaster knowledge about disasters from a workshop held a year before as a part of the government education for disasters program. The second group (Group B) were 10 students without knowledge about disasters from 5th grade (15-17 years old).

Figure 3-17 Group A students during survey in their classroom

Figure 3-18 Group B students during survey in their classroom

3.8.3 Class practices

It is not surprising, that those students who did not participate in the educational disaster program are less prepared and have a lower level of disaster risk perception than those residents who took part in the program and participated in the drill.

A questionnaire survey about landslide awareness and preparedness between the two groups of students were carried out before and after an evacuation practice held in a neighborhood closeby. This practice will be explained in the next chapter.

The questionnaire survey before the forum was carried out in March 2015, a week before the practice was held. The questionnaire survey after the practice was carried out in the school the same day of the practice. I carried out both surveys with the collaboration of one of the instructors who worked a year before in the government disaster program.

The purpose of the survey after the practice was to collect information about how the students perceived the practice. They received a simple map of the practice area, and they described how they did the practice and what they thought would be an effective way to evacuate the area.

Students in both groups answered independently and after the surveys were completed we discussed their responses.

At the end of the practice, all the students created one map with the best option for an evacuation of the study area if a landslide were to happen.

Figure 3-19 Group without experience working in their maps

Figure 3-20 Group with experience discussing about their ideas

Figure 3-21 All students creating evacuation map suggestion

3.9 Conclusions

For disaster risk mitigation and reduction it is necessary to establish institutional frameworks for community empowerment.

In order to develop cultural willingness and preparedness for landslide and other disasters mitigation and reduction, La Paz neighborhoods need to develop these types of initiatives and methodologies.

Community abilities can increase resilience and have an effective landslide risk management through Public awareness, responsibility, commitment, community participation and coordination. However, it is important to consider some aspects in case of La Paz which are: There is not enough information related to public awareness and there is a lack of effort for the community for active participation. Although there are some basic tools and strategies, La Paz has not developed a well-planned and structured approach as of yet.

It has been evidenced that educating the general public through children in the early levels of their education is another nonstructural mitigation approach. This approach has been increasingly used in disaster mitigation strategies with positive and promising results

As Izadkhah (2005) argues, children, as the assets and leaders of the future, can learn to protect themselves and their environment in the future through a global culture of mitigation. This can enhance their own, their families' and their community's safety as they grow up. Children are considered as 'powerful forces' in behavioral change for the next generation.

An educational program related to disaster risk management should become an integral part of the school curriculum. Additionally, if an effective awareness raising and appropriate information dissemination to all community levels are to be achieved, the adverse aspects presented in this chapter should be identified and considered. It is hoped that the continuous implementation of initiatives related to disaster education for children in different developing countries, will result in an evident increase in knowledge and awareness of the community and thus create more resilient communities in the future (Izadkhah, 2005).

In order to have an effective landslide risk management in La Paz an increase in its resilience is necessary to develop an integral process. The final goal will be achieved in the medium to long term if all the segments involved commit themselves to the implementation of effective risk management. During this period, the intention of this work is to suggest a simple but effective evacuation strategy and its application in the short term in all neighborhoods located in high risk areas prone to landslides or other types of hazards. This strategy consists in providing a compelling graphic evacuation plan for communities inhabitants. This simple plan will show how, where to and why the persons should evacuate their neighborhood in case of a disaster. The next two chapters will explain in detail with an example the creation, use and application of this tool.

CHAPTER 4: EVACUATION PRACTICE AND SIMULATIONS FOR A NEIGHBORHOOD IN LA PAZ CITY

4.1 Evacuation Practice

4.1.1 Participants' selection

The goal of the practice was to collect data and to perform observations on the evacuation behavior of people in slope movements and on stairs in a real location and environment. Here, speeds and evacuation times were to be collected.

In order to understand the evacuation behavior of people in a real environment, a neighborhood was chosen for the experiment. In order to get information on a situation, as close to an emergency as possible the experiments were announced evacuation practices.

They were announced in the sense that the groups of persons involved knew when the practice would be held, but not the specific area. In the case of the group of students the authorities of the school they belong to were made aware of the day and the location of the practice.

In this group of people the average shoulder height is assumed to be 1.50m. There was no one that had any movement disability and all were fit and healthy.

The practice has been assumed to determine the normal walking speed of the test group only, and not a simulated evacuation speed for everyone or for conditions that may present during an evacuation in a real emergency situation. It can be assumed that the velocities during an evacuation may be higher than the velocities found during a normal situation. The velocities that are found in this experiment could be roughly assumed to be approximate evacuation velocities for the average adult population.

The group of students selected for the practice was divided in two sub groups, the first sub group was 22 6th grader students, aged between 16 and 17 years old. The second sub group was 10 5th graders aged between 15 to 17 years old.

In order to have a better range of data, another two groups were added to the practice. One of 10 people aged from 30 to 40 years old, and a third one with people from 50 to 70 years old. The number of each group participants is based on the actual demographics presented in the study area.

	Age	Disaster education	Number of participants
Group 1	15-17		
	Sub group A	Yes	16
	Sub group B	No	10
Group 2	30-40	No	10
Group 3	50-70	No	8

Table 4-1 Participants of the evacuation practice

The total practice population consisted of 44 persons, 26 in the age group of 15-17 years, 10 in the age group of 30-40 years and a third one with people from 50 to 70 years old.

Figure 4-1 Both groups of students in study area practice

Figure 4-2 Group 2 (30 to 40 years old) in study area practice

Figure 4-3 Group 3 (50 to 70 years old) in study area practice

A warning method was not used in this experiment, since all the people were not actually residents of the selected neighborhood, the used method was to measure velocity, distance, time and behavior between two checkpoints in 7 different routes.

Since part of the main investigation is to use a disaster management program for the community from a different approach, the student population was the principal subject for this program application. This work focused on this demographic in order to obtain additional data used in the main final research document. At the same time, a practice where all the neighborhood inhabitants would be willing to participate was not possible under any circumstances.

Figure 4-4 Group of students walking through a selected path for practice

Figure 4-5 Students groups descending irregular exterior stairs

4.1.2 Equipment and staff

5 cameras were used to record the practice, external helpers operated the cameras, the video footage was used to manually extract the necessary data. This included locating occupants in the practice area, measuring evacuation times, and measuring walking speeds.

This information was additional to chronometers that were given to each participant in order to measure the time they make in each route individually. This helped to have an accurate movement time of the participants.

Figure 4-6 Collecting time data from students' chronometers

4.1.3 Time data collection

The data were taken as follows: Each person has completed a route when he or she has passed the checkpoint determined at the beginning of the practice.

For instance, on one of the routes, from start point to finish point, the path changes from a flat almost horizontal street to a route of stairs over a 35 degree slope. The route changes but in order to have an average time and velocity information the evacuation route is not complete until the mark point is reached, by using all the stairs, which in that case were more than 149 steps.

The evacuation time for an individual is therefore the time from the start of a rout until the person has completed the evacuation path according to the definition above and the total evacuation time for each group is the time from the start of rout until the last person has completed the evacuation.

4.1.4 Location

The neighborhood called "Cino Dedos" was selected because it presents the best scenario to run this practice. Being an urban area in development, the population is relatively young and there is still space to grow.

Located on the high part of a mountain, the characteristics of this area is the same as most of the dwellings settled on the steep hills that surround La Paz. Also Cinco Dedos is a moderate to high risk neighborhood.

Figure 4-7 General view of Cinco dedos neighborhood

The geophysical information of this area was used to create a digital model that will be the base for the evacuation simulation, run in special emergency egress simulator software.

4.1.5 Paths

Cinco dedos presents different paths with different characteristics, dirt roads, stone streets, asphalt streets and avenues. Also, all of them have different slope degrees in their length, from almost horizontal to paths with more than 35 degrees.

Figure 4-8 Exterior stairs in study area

Figure 4-9 Dirt roads on the upper sector of the study area

Figure 4-10 Horizontal asphalt street with river channel beneath

Figure 4-11 Stone street with less than 10 degrees slope

Figure 4-12 Steep asphalt avenue

4.1.6 Non- continuous exterior stairs

The primary data we collected was participants' movement on stairs during the evacuation practice together with time, distance travelled, stair geometry and configuration.

Figure 4-13 Students group ascending irregular stairs in evacuation practice

Figure 4-14 Configuration of exterior irregular stairs in study area

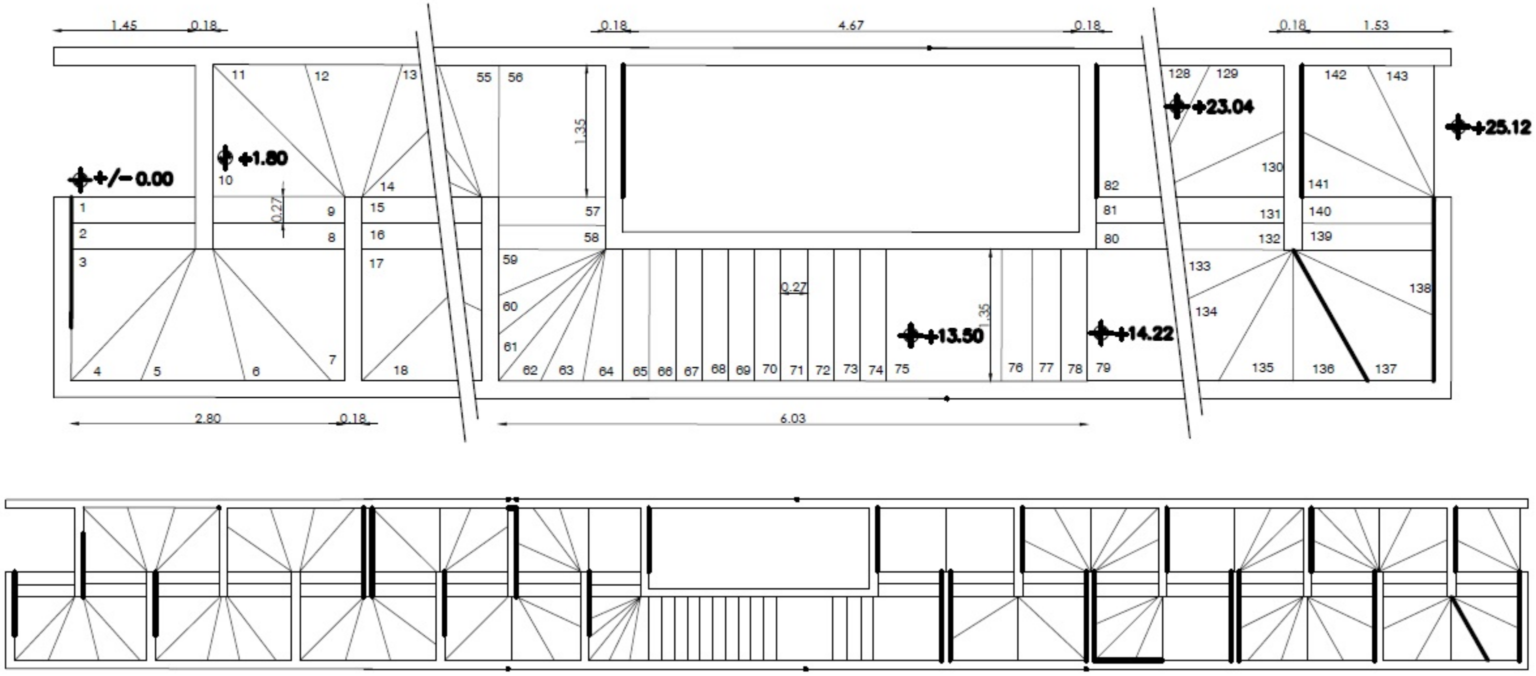


Figure 4-15 Configuration of standard exterior stairs of study area

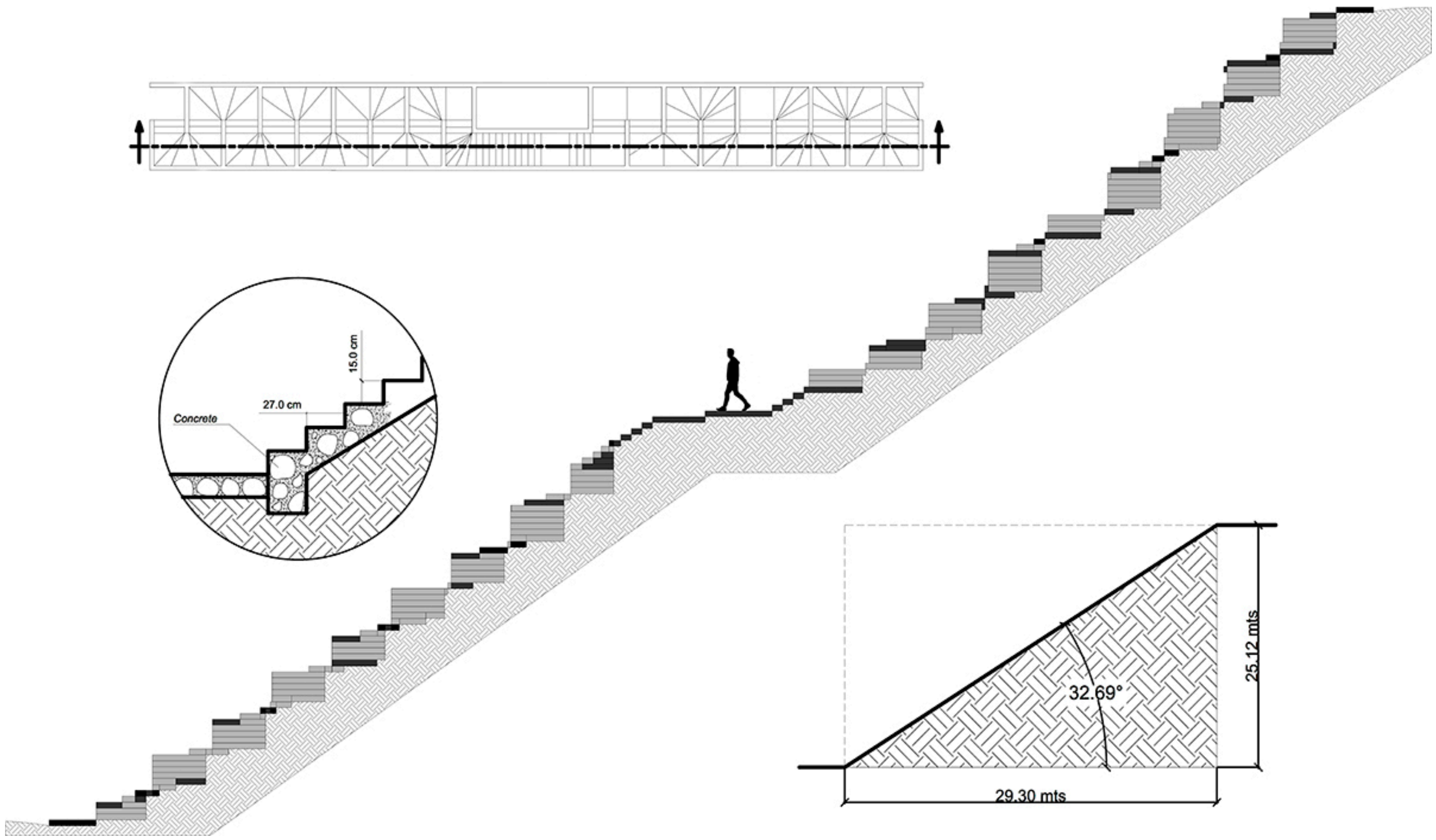


Figure 4-16 Section of exterior stairs configuration, inclination and construction detail

4.1.7 Participants behavior

Behavior of participants was based on the stairs configuration. On a selected stairs of the study area, groups performed the evacuation practices independently. With the same physical characteristics, they did not need to overtake other group participants during the practices.

Figure 4-17 Students group 1 ascending stairs in practice

Figure 4-18 Group 1 and group 3 descending stairs in practice

On stairs with winder steps, the minimum winder tread depth at the walk line should be 10 inches (254 mm) from the side where treads are narrower. The total width of stairs is thus inevitably reduced (IBCS, 2009). Also, the opposite part of steps has a non-usable area when people walk on them, preventing the possibility of overtaking others.

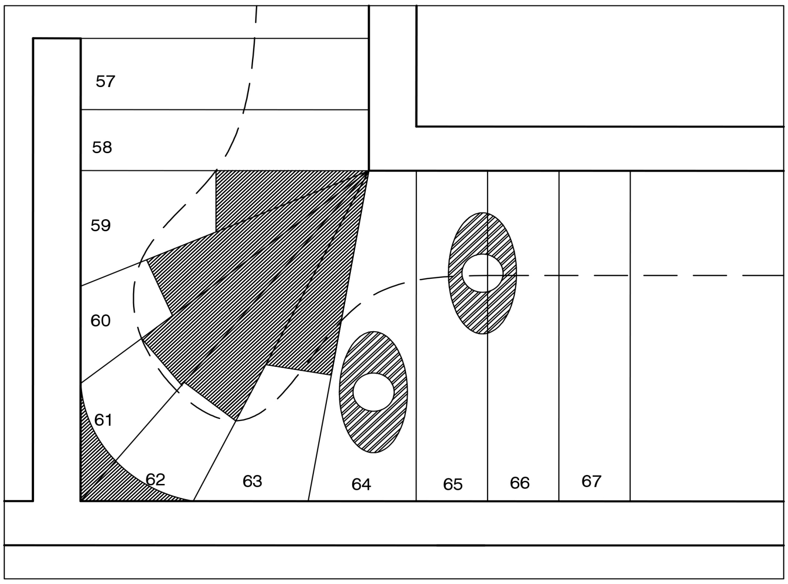


Figure 4-19 Stairs winder minimum width at walk line area

Figure 4-20 Students group 1 walking over stairs winder, creating only one line flow

Students having to hold the railing because she is stepping over the narrow area on the stair winder

Figure 4-21 Students group 1 descending stairs with difficulties

4.1.8 Velocity on stairs and slopes

As we had expected, results of velocity on stairs was adjusted based on stairs access, geometry and linear length, showing results for a constant velocity independent of the distance between participants.

This meant that when the distance between persons was decreased, as reported by other researchers, velocity would also decrease (Frantzich, 1996). Even so, our study data defined a constant velocity for all groups. All sets of stairs had the same outline because they were part of the same Barrios de Verdad design development program, i.e., an effective stair width of 1.35 to 1.50 m.

Each experiment was run one time only for each group in all the routes.

4.1.9 Distances

The distances the groups walked for the practice are detailed in the next graphics.

Distance 116mts
Steeper than 10 degrees street
Going up
Slope degree 13.6

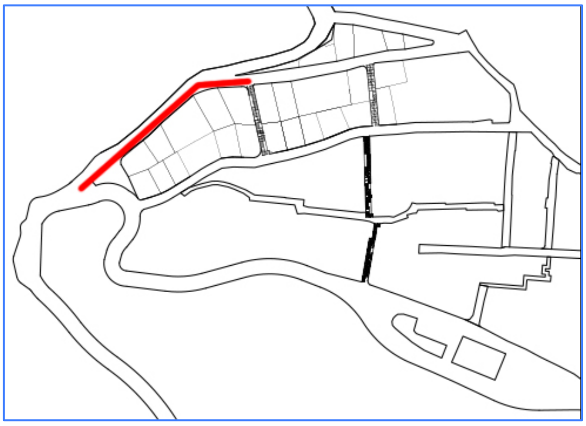


Figure 4-22 1st Path traveled in practice

Distance 175.5mts
Steeper than 10 degrees street
and flatten than 10 degrees
Going up
Slope degree 13.6/3.62

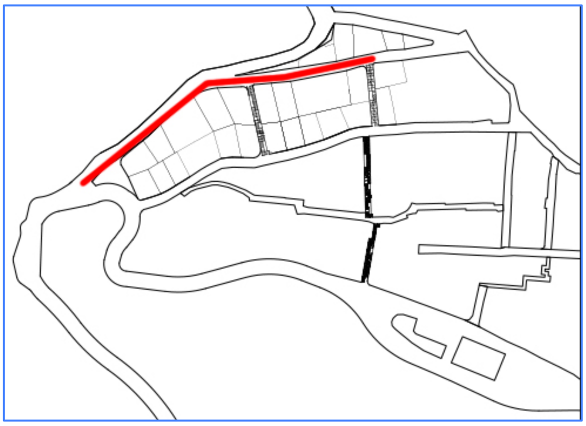


Figure 4-23 2nd Path traveled in practice

Distance 202.82mts
Flatten than 10 degrees street
and exterior stairs
Going up
Slope degree 2.46/38

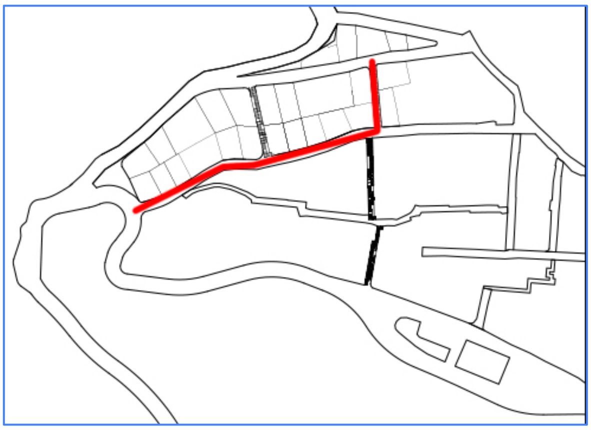


Figure 4-24 3rd Path traveled in practice

Distance 72.10mts
Flatten than 10 degrees street
Going up
Slope degree 2.46

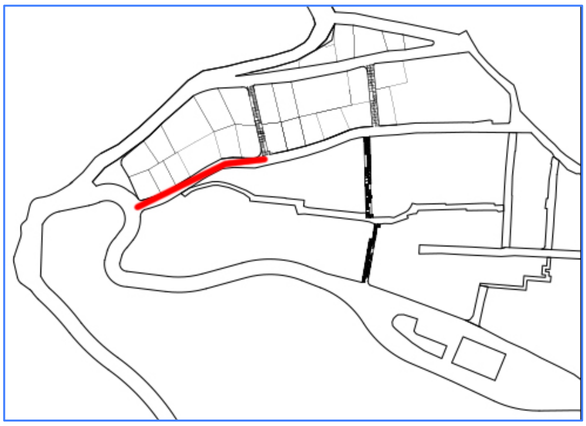


Figure 4-25 4th Path traveled in practice

Distance 209.30mts
Flatten than 10 degrees street
and exterior stairs
Going down
Slope degree 38/3.62

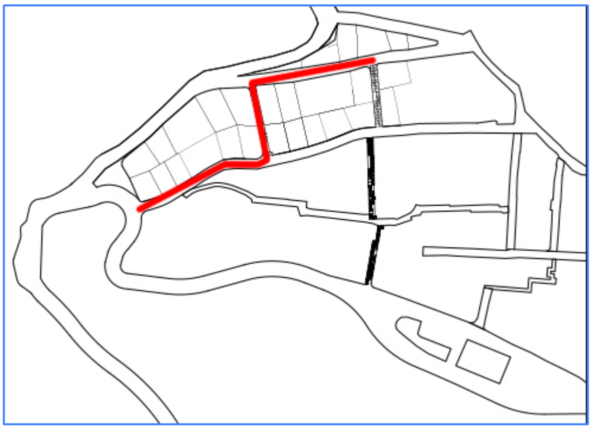


Figure 4-26 5th Path traveled in practice

Distance 161.70mts
Exterior stairs and
Steeper than 10 degrees street
Going down
Slope degree 38/13.3

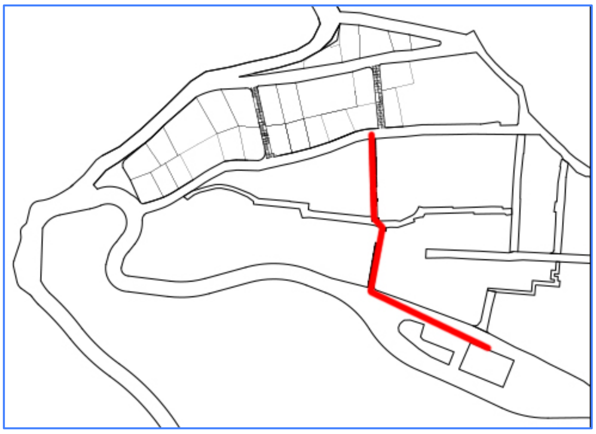


Figure 4-27 6th Path traveled in practice

Distance 240.15mts

Steeper than 10 degrees street

Going down

Slope degree 13.3

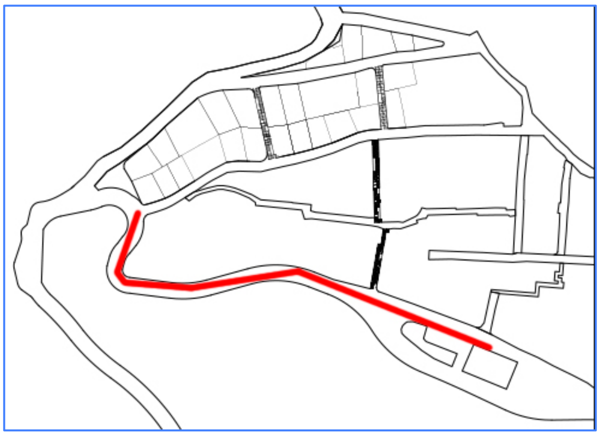


Figure 4-28 7th Path traveled in practice

4.1.10 Processed data for simulation input

The next table presents an overview of the measured average walking velocity per group in different slope paths, the distance they traveled and the slope degree of the paths selected for the practice.

			Average velocity (m/s)				
Groups	Age	Number of persons	Flatter than 10 degrees street	Steeper than 10 degrees street		Irregular Exterior Stairs	
				Going up	Going down	Going up	Going down
Group 1	15-17 years	26	1.24 m/s	0.78 m/s	1.11 m/s	0.41 m/s	0.75 m/s
Group 2	30-40 years	10	1.20 m/s	0.65 m/s	1.09 m/s	0.38 m/s	0.69m/s
Group 3	50-70 years	8	1.09 m/s	0.48 m/s	0.93 m/s	0.18 m/s	0.35 m/s
			Distance (meters)				
			133.40 mts	116.00 mts	240.15 mts	37.30 mts	137.70 mts
			Slope degree				
			3.86	13.6	13.3	38	38

Table 4-2 Data processed for simulation input

4.2 Simulation

Computer simulation of pedestrian movement is a useful method to help designers to understand the relation between space and human behavior. This research is a proposal of application of a computer simulation model to the analysis of pedestrian movement. The characteristic of this model is the ability to visualize the movement of every pedestrian in the plan of a design project as an animation. This model can show the flows and stagnations of pedestrians in the plan. So designers can understand where stagnations and congestions are occurring and where the dangerous place is, and then they can use the result of simulations to improve their design projects.

In this work, first the outline of the 3D model is explained, and then application examples are shown. Regarding the application of the simulation model, safety and queuing problems are mainly discussed. These two problems often occur in a lot of architectural and urban spaces. The simulation examples show that this model can be reasonably applied to those problems and that they are effective for improvement of design projects.

4.2.1 Outline of the Simulation Model

4.2.1.1 Pathfinder

Extract from TEP Technical Reference, 2015

Pathfinder is an agent based egress and human movement simulator. It provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis. Pathfinder includes a graphical user interface that is used primarily to create and run simulation models.

Robust Import Options

Pathfinder provides support for the import of AutoCAD format DXF and DWG files. Pathfinder’s floor extraction tool makes it possible to quickly use the imported geometry to define the occupant walking space for the evacuation model.

Occupant Movement to Exits

By default, each occupant (agent) uses a combination of parameters to select their current path to an exit. The agent responds dynamically to changing queues, door openings/closures, and changes in room speed constraints like debris. The user can modify the default parameter weights to change the behavior.

Customizable Populations

Each person in the model acts as an agent with their own profile (such as size and walking speed) and their own behavior (such as exits, waits, and waypoints). Based on their characteristics, each person uses their local environment to make decisions on exit paths. Multiple profiles can be created and assigned to different populations. Parameters in each profile can be described using constant, uniform, standard normal, or log normal distributions.

Powerful Results Evaluation

Display of 3D results is available both during the calculation (to view current status) and immediately on completion. The 3D display allows the user to interactively display occupant movement, run back and forward in time, view paths, and select people to watch. A summary output file includes min, max, and average exit times and first-in and first-out times for rooms and doors. As the positions at each time step are recorded the velocities and turning rates are recorded and can be analyzed in a spreadsheet program such as MS Excel.

Model Representation

The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data (e.g. FDS geometry).

Walls and other impassable areas are represented as gaps in the navigation mesh.

Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow.

Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between stairways and the connecting doors.

Each occupant is defined by position, a profile that specifies size, speed, etc., and a behavior that defines goals for the occupant. The occupant is represented as an upright cylinder on the movement mesh and movement uses an agent-based technique called inverse steering. Each occupant calculates movements independently.

Simulation Modes

Pathfinder supports two movement simulation modes. In "Steering" mode, doors do not act to limit the flow of occupants; instead, occupants use the steering system to maintain a reasonable separation distance. In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density.

Floors

Floors are the primary method of organization in Pathfinder. At their most basic level, they are simply groups in which rooms, doors, stairs, ramps, and exits can be placed, but they also control the drawing plane for most tools and filtering of imported geometry.

Rooms

Rooms are open space on which occupants can freely travel. Each room is bounded on all sides by walls. Rooms can be drawn so that they touch each other, but an occupant can only travel between them if they are connected by a door.

Speed Modifier: A time-variable factor that affects the speed of each occupant who travels in the room. When occupants travel in the room, their maximum speed is multiplied by this factor. This could be used, for instance, to represent the effect of smoke on occupant speeds. By default, the modifier is 1.0 throughout the simulation.

Doors

In Pathfinder, occupants cannot pass between two rooms unless they are joined by a door. Also, the simulator requires that each occupant must have a path to at least one exit door. Doors provide useful flow measurements in simulation results.

Stairs

Stairs in Pathfinder are represented by one straight-run of steps. One requirement of all stairs for successful simulation is that each end of the stairs must connect to boundary edges of the rooms, meaning that there must be empty space at the top of the stairway and empty space below the bottom.

Profiles

Pathfinder uses an occupant profile system to manage distributions of parameters across groups of occupants. This system helps you control the occupant speed, size, and visual distributions.

The Characteristics tab provides the following parameters:

- Priority Level: the priority of the occupant. Higher values indicate higher priority. This allows occupants of lower priority to move out of the way of those of higher priority. This would be useful when simulating first responders that must be able to move easily through a crowd of occupants. Priority values are completely relative. For instance, if three occupants meet of priorities 4, 6, and 12, they will behave the same as if their priorities were 0, 1, and 2, respectively.
- Speed: specifies the maximum speed an occupant may travel in an open room.
- Shoulder Width: the diameter of the cylinder representing the occupant. This is used for collision testing and path planning during the simulation. This value will also affect how many occupants can be added to a room without overlapping.

The Movement tab provides parameters related to how occupants use their surroundings:

- Use Stairs: whether the occupant can use stairs to evacuate. This may be useful to model occupants with physical impairments.
- Height: the height of the cylinder used for inter-occupant collisions. This is useful for limiting collisions that might occur between occupants on different floors when

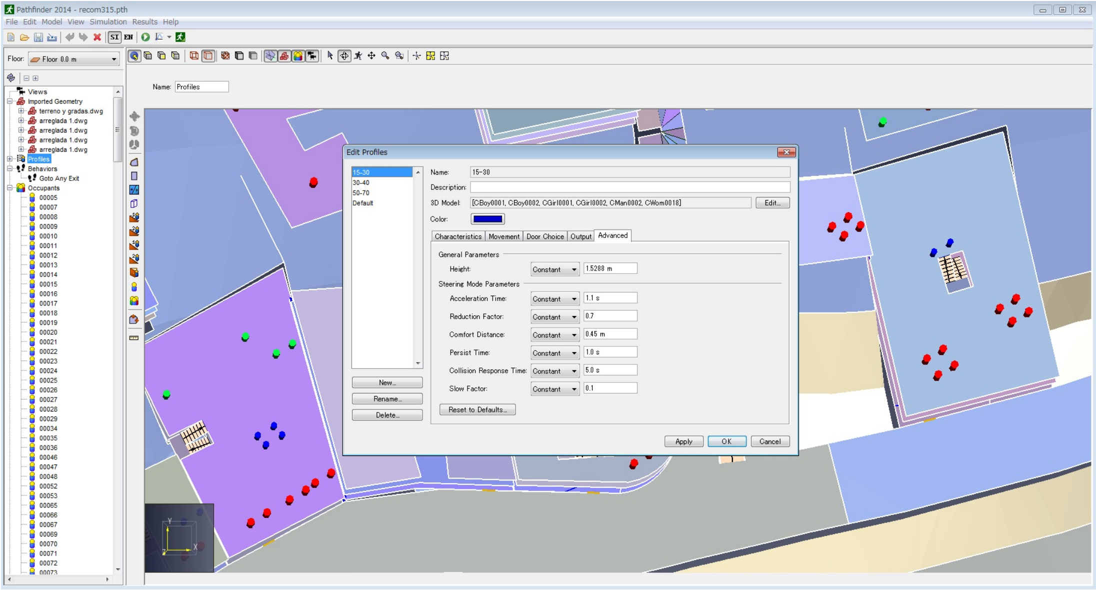
the floors have been modeled close together.

- Acceleration Time: a Steering Mode parameter that specifies the amount of time it takes for the occupant to reach maximum speed from rest or to reach rest from maximum speed. The resulting acceleration of each occupant is max_speed/accel_time.
- Comfort Distance: specifies the desired distance one occupant will try to maintain with others nearby such as when waiting in queues.

Each occupant in the Pathfinder model is linked to one profile. Profile parameters can be edited in the profiles dialog at any time and the occupants using that profile will be automatically updated. Occupants' profiles can be set when adding the occupants or by selecting the occupants after being created and editing the Profile box in the property panel.

Behaviors

Behaviors in Pathfinder represent a sequence of actions the occupant will take throughout the simulation. For every behavior, there is an implicit action to move the occupant to an exit. This implicit action will always happen last. Additional intermediate actions may also be added that can make the occupant wait or travel to a non-exit destination, such as a room or point.



Name: Profiles

Name: 15-30

Description:

3D Model: [CBoy0001, CBoy0002, CGirl0001, CGirl0002, CMan0002, CWom0018]

General Parameters

Height: Constant 1.5288 m

Steering Mode Parameters

Acceleration Time: Constant 1.1 s

Reduction Factor: Constant 0.7

Comfort Distance: Constant 0.45 m

Persist Time: Constant 1.0 s

Collision Response Time: Constant 5.0 s

Slow Factor: Constant 0.1

Figure 4-29 Dialog box of pathfinder to input parameters

Adding Occupants

Occupants can be placed individually in the 3D or 2D view, distributed in a rectangular region of a particular room, or distributed through the entire area of a room or multiple rooms.

Simulating - Output Parameters

The Output tab provides the following options:

-Jam Velocity: controls the speed threshold at which occupants are recorded as being jammed in the Occupants output file.

The Paths tab provides the following options:

-Max Agent Radius Trim Error: this parameter affects how accurately occupants can navigate through tight spaces when the occupants in the simulation have varying sizes. The larger this value is the less likely an occupant is to navigate through a space that has a width close to their body diameter. With larger values, however, the simulation will consume less memory and start faster (sometimes much faster if every occupant has a different size). Each occupant is guaranteed to be able to fit through a space with width equal to the occupant's diameter plus twice this value.

Behavior Parameters

The Behavior tab allows you to set options for Pathfinder's two primary simulation modes: SFPE and Steering. To select a simulation mode, choose SFPE or Steering from the Behavior Mode drop-down box.

Steering Mode Parameters

The Steering mode is more dependent on collision avoidance and occupant interaction for the final answer and often gives answers more similar to experimental data than the SFPE mode (i.e. steering mode often reports faster evacuation times). Door queues are not explicitly used in Steering mode, though they do form naturally.

The Steering mode supports the following options:

- Steering update interval: specifies how often (in simulation time) to update the steering calculation. This could also be considered to be the cognitive response time of each occupant. The higher this number, the faster the simulation will run, as long as the simulation time step is less, but the poorer the decision making skills of each occupant will be.
- Collision Handling: controls whether occupants avoid one another and can collide with each other. (TEP, 2015)

4.2.2 Study area 3D Generation - Process and Input Parameters

The study area was generated as a 3D model. This was important because of the geographic characteristics of the terrain and the appropriate location of the stairs. From the beginning it was necessary to create an accurate environment so the final result would be closest to a real situation. Once the 3d location model was imported to Pathfinder, it was necessary to select areas and paths that could be used as "rooms" and "floors" for the evacuation simulation.

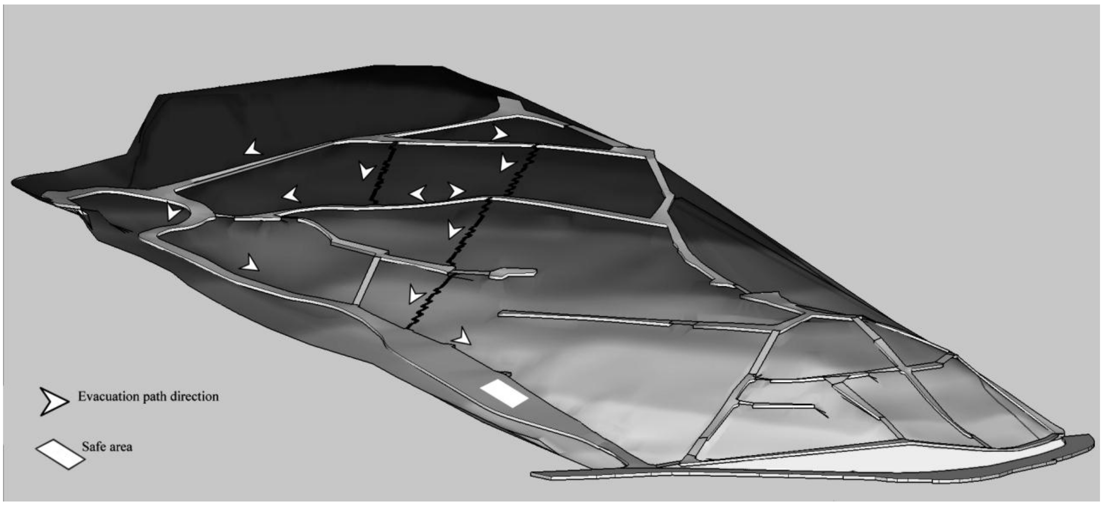


Figure 4-30 Terrain mapping of the study area

4.2.2.1 Agents

The agents were generated in three separated groups based on the practices in the field. Each group had parameters introduced based in the practice results. These parameters, "profiles" in the software were divided into three demographic groups.

Group	Age	Speed m/s	Shoulder width cm	Height cm	Comfort distance cm
1	15-30	1.2	40.58	153	30
2	30-40	1.1	49.58	172	30
3	50-70	0.68	45.58	162	30

Table 4-3 agent's data input parameters for simulation

4.2.2.2 Behavior

The input behavior was carried out in the same way for every agent and the goal was for the agents to go to an exit selected. In the simulation case the exit was a “door” located in the same area as the safe zone determined in the practice.

4.2.2.3 Velocity

The individual velocities were adjusted to values obtained from the evacuation practices. For each group the average walking speed was measured on low slope areas to steep slope areas, and most importantly climbing and descending velocities were measured on stairs. Since no congestion occurred, these average speeds were used as input for velocity.

4.2.2.4 Paths

Each group ran the simulation independently over the same path as the field practice. They moved from a selected point to the exit used in all the simulations. The results were used to compare with the data obtained in the practice. The evacuation velocity for each simulated agent presented in this paper is the result of the average of the 7 simulation runs practice.

4.2.3 Jam time

A basic definition of jam time would be to have almost absolute zero velocity over a minimal time interval. The minimal time interval is needed to avoid very short velocity reduction at a sharp turn for instance.

Up to now Jam time has not been an important aspect of the evacuation analysis. The period of time a pedestrian stays in jam should be implemented in any route selection strategy. This work considers pedestrians moving at a speed lower than 0.25 m/s (Seyfried, 2010) as being in a jam situation.

In recent years pedestrian dynamics has gained more importance and a lot of attention due to continuously growing urban population and cities combined with an

increase of mass events.
This sets new challenges to architects, urban planners and organizers of mass events. One of the main goals is an effective use of the designed area of evacuation, for instance by minimizing jams thereby optimizing the evacuation flow.

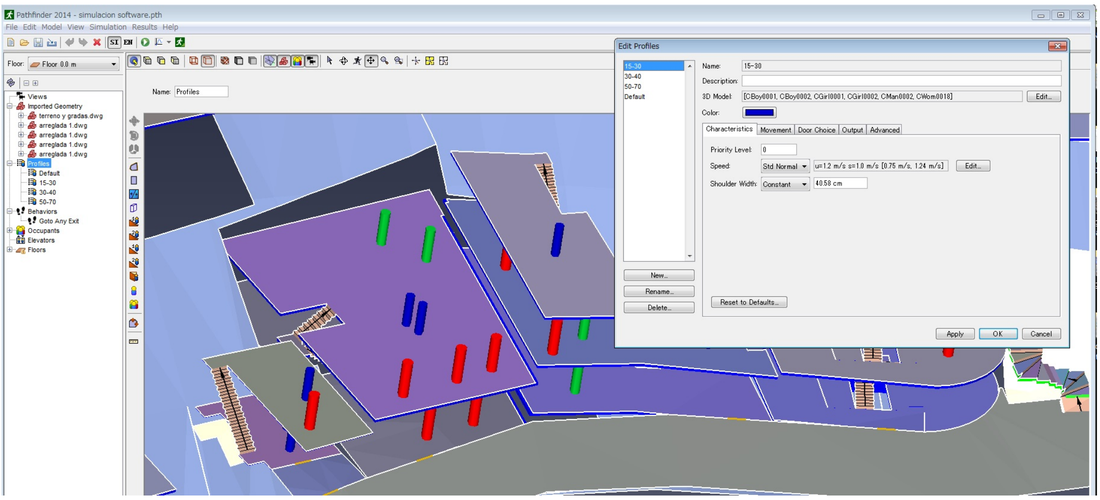
In any evacuation situation, the motivation of each pedestrian is to leave the affected area. The events used to redirect pedestrians include the identification of a jam situation and/or identification of a better route than the current one. The fundamental behavior of humans in the case of an evacuation is generally to follow the seemingly quickest path, and this is more so when they do not have any evacuation plan nor education about a proper evacuation behavior.

The most used criteria are the overall evacuation time and a visualization of the evacuation process at specific times. In this paper we elaborate other criteria to address the criticality of an evacuation simulation. The analyzed criteria are the maximum individual time spent in a jam and the total jam evolution over time.

A special credit was given to the time pedestrians spend in jam during the evacuation and the maximum time an individual spends without the capacity of moving towards another path that lead them to the exit.

4.3 Simulation process

The procedure during the simulations was as follows.
The simulated evacuation drills of Cinco Dedos neighborhood were initiated with all inhabitants being generated in their houses. The input data for the agents in each house is based on real information, the people who live there were divided in three groups following the same groups as for the practice. Then, people will start the evacuation. Assuming that the pre-evacuation behavior will be to keep still for few seconds after an alarm is given. The pre-evacuation times measured during the experiment for each room (house) in the experiments are used as input.



Floor: Floor 0.0 m

Name: Profiles

Name: 15-30

Description:

3D Model: [CBoy0001, CBoy0002, CGirl0001, CGirl0002, CMan0002, CWom0018]

Color: 🟦

Priority Level: 0

Speed: Std Normal u=1.2 m/s s=1.0 m/s [0.75 m/s, 1.24 m/s]

Shoulder Width: Constant 40.58 cm

Figure 4-31 Agents generated in their house prior evacuation simulation

Pathfinder allowed the people to start walking towards the safe area at the moment the simulation time equaled these pre-evacuation times. Therefore, the prediction errors are related to the process of walking from the group rooms towards the safe area, the pre-evacuation times are left out.

Adults were not distinguished from the children under 15 years old in the simulations, since they often stayed together with their designated guardian or a close adult during the evacuation, especially children aged 0-10 years.

The same parameters were taken for people older than 70 years old.

The three different agent groups were distinguished in the simulation, since they often stay together with children and elderly people, they were modeled as the agent closer in age to one of the three groups.

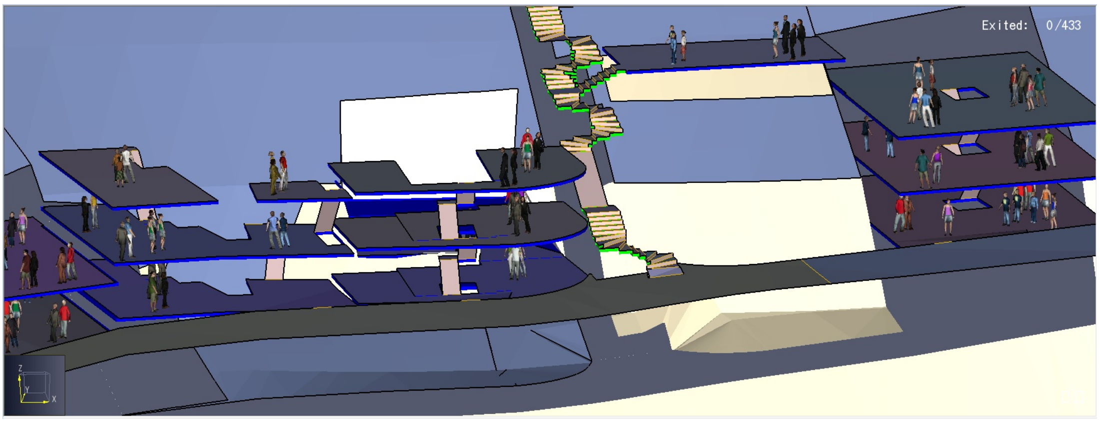


Figure 4-32 Agents with different profiles are shown in selected color

This was possible since Pathfinder has group behavior feature implemented.

The individual velocities were adjusted to values obtained from the evacuation practices. For each group the average walking speed on low slope to steep ones, and most important stair climbing and descending velocities were measured.

Since no congestion occurred during the evacuation practice, these average speeds could be used as input for the free speeds. The observed speeds in table 2 are in good agreement with values obtained in other sources

The evacuation time for each simulated agent presented in this work is the result of the average of the 7 simulation runs practice.

Some stairs discharged directly to a street to walk through, other discharged into streets to cross them only and continue going through another set of stairs.

All the stairs in the simulation have the same configuration as the real design stairs components in the research area. This in order to obtain the most accurate results from the software simulation.

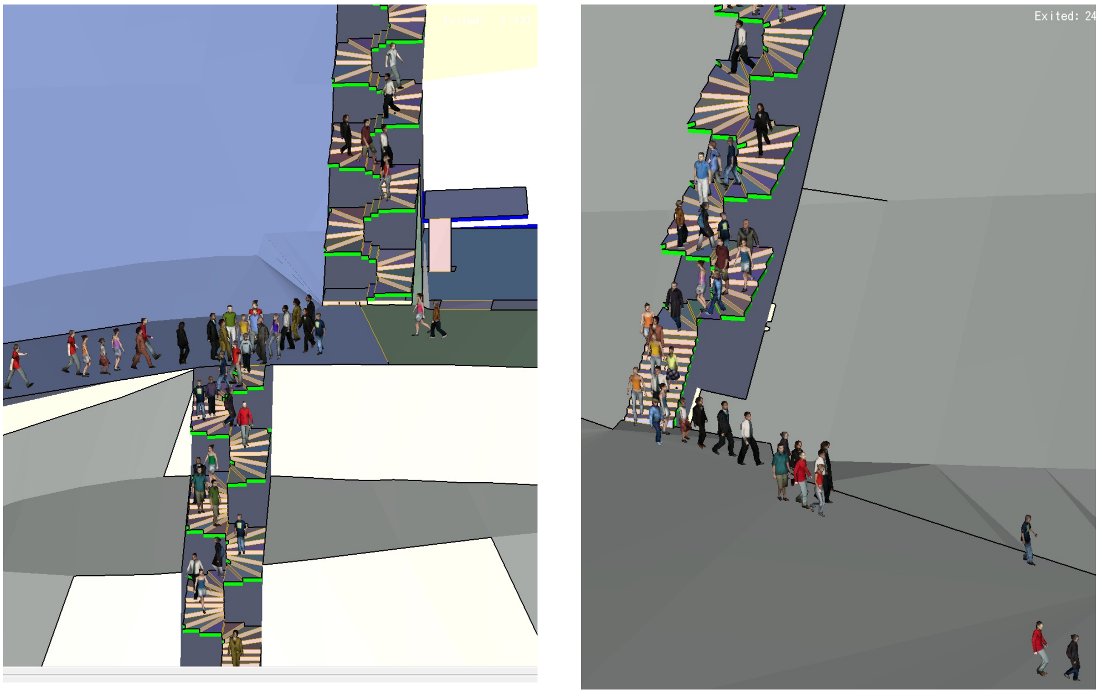


Figure 4-33 different paths characteristics for evacuation simulation

4.4 Simulation based on evacuation practices

For simulation, agents were generated based on the practice participants. With each group of agents modeled to move along individual digitized paths that we composed from routes used in the practice. All agents had the same input behavior, i.e., to go to the designated safe area. Agents were generated for the three separate groups. Average walking velocity on low to steep slopes and stair descend velocities were introduced as parameters. Average body measurements, e.g., shoulder width and height, were also input. Parameters added to agents “profiles” are shown in Table4-3.

Participants were generated as agents for the simulation. Each group of agents was modeled to move along one of the digitized paths composed by us from the routes performed in the practice. The input behavior was the same for every agent, which was to go to the safe area designated in the practice.

The initial location of the agents in the simulation was the same as the location where all the practice participants started the movement toward the safe area. This safe area was generated in the same region as the one designated for this purpose in the practice.

This parameter is important because it can be used to obtain a prediction of the time the occupants of an urban area will spend in case of an evacuation. Another parameter is the speed reduction because of the configuration of the stairs.

4.5 Simulation of the current situation

Simulated evacuation of the Cinco Dedos neighborhood was initiated with all agents generated in their houses. Each building from the area was generated based on real constructions. Population data was developed from door-to-door interviews with residents, house-by-house data including numbers of family members and ages were collected in July 2014. There were 169 inhabitants in a 9,640 m^2 area containing 29 buildings on 31 properties. All members of families were assumed to be at home when simulation started.

The number of evacuees in a landslide event was set based on the following:

- It is early in the morning.
- All inhabitants are at home.
- It is raining heavily

Based on the above assumptions, the total number of evacuees was 169.

4.6 Simulation Cases

Two cases were simulated under different evacuation scenario conditions -- both with the same input data for the environment, agent profile, behavior and evacuations paths.

Case 1 enabled the program to choose the shortest path as the primary evacuation route. Software therefore used a combination of parameters to select the current path to the closest exit.

Case 2 was an improved evacuation plan that was more effective and safer and where following the shortest path was not the primary action. The primary action was instead to separate evacuation paths by neighborhood block.

Adults were not distinguished as separate from children under 15 years of age in simulation because children usually stayed close to older persons during evacuation, especially children 0-14 years old. The same parameters were used for persons over 70 years old. Those under 15 and over 70 years old agents were modeled as agents closest in age to members of the three groups. This was possible because agent-based evacuation software had a group behavior feature implemented.

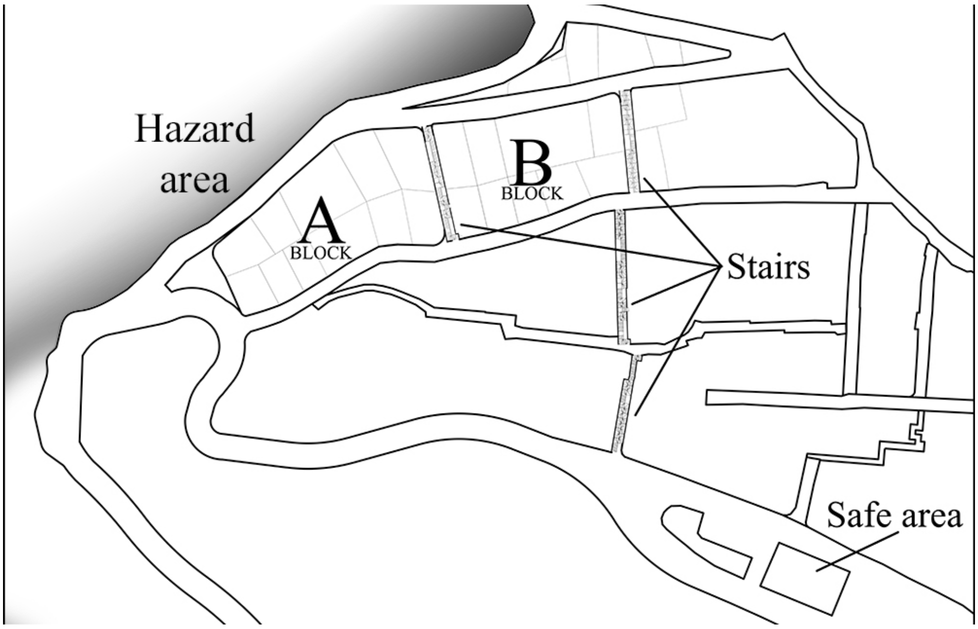


Figure 4-34 Study area divided by blocks

4.7 Simulation and projection

Part of this research was carried out to predict the results of an evacuation in the future.

Cinco Dedos is not a fully developed area and it is the ideal location for new settlements since this is one of the neighborhoods closest to the center of La Paz.

The number of agents input increased from 169 to 315. The number of projected evacuees was based on the percentage of built and occupied area compared to already developed neighborhoods where 100% of the area is covered by dwellings. The Cinco Dedos neighborhood has 57% of its area covered by buildings, and government authorities and technicians predict that this area will be fully covered by houses in the near future. As before, two simulations were run, i.e., cases 1 and 2. Both had the same input data for the environment, agent profiles, behavior and evacuations paths.

This data will become an important tool in creating disaster management programs for La Paz neighborhoods, mainly programs related to evacuation in the case of landslides. Evacuation simulation provides evacuation plans for neighborhoods where drills are not possible because not all residents are willing to take part in them.

4.8 Conclusions

This data will be an important tool to create disaster management programs for La Paz neighborhoods, principally programs related to evacuation in case of landslides. Evacuation simulation can provide plans for neighborhoods where drills and practices are not possible since residents are not 100% willing to participate in them.

CHAPTER 5 RESULTS AND DISCUSSION

This chapter starts with the qualitative results from the observations during the practice, followed by the quantitative results from the experiments and finally a comparison between the results from Pathfinder and the data from the practices. The results of this comparison will allow the software to adjust the parameters so the simulation results will be close to the real data obtained from the practice. With these parameters fixed and calibrated, the software could be used as a tool for future disaster management program analysis and recommendations.

5.1 Quantitative analysis of the evacuation practice

Overall, evacuation process was similar in all three groups practices. After receiving a signal to evacuate, people would start the chronometers and move toward the final point of the rout selected.

In general, the evacuations proceeded smoothly and the three groups of people followed the instructions with no issues.

People in the younger age group were often excited to do the practice, whereas the older participants seemed more serious and confused. Certain delays could be noticed in the process.

For every group route practice the premise was to walk fast as it was raining and they were without umbrellas in order to measure the speed in a more realistic fashion. People did not run but they did not stroll either on the routes.

The main results of the practices are the movement velocities of individuals on irregular and non continuous stairs located as principal pedestrian ways in their neighborhood. This parameter is important because it can be used to obtain a prediction of the amount of time the occupants of an urban area will take in case of an evacuation.

Another parameter that may be of interest is the speed reduction because of the configuration of the stairs. This may be caused by the tendency of the participants to stay away from the non-usable spots on the stairs. While a velocity decrease was not observed in these experiments when the occupants came close to these points, there was a tendency from them to keep a distance away from these areas.

To create this comparison between the practice data and the simulation results, only one rout was selected from the practice to be simulated, the selected path presents two sets of stairs, one of them a principal exit rout in case of an evacuation.

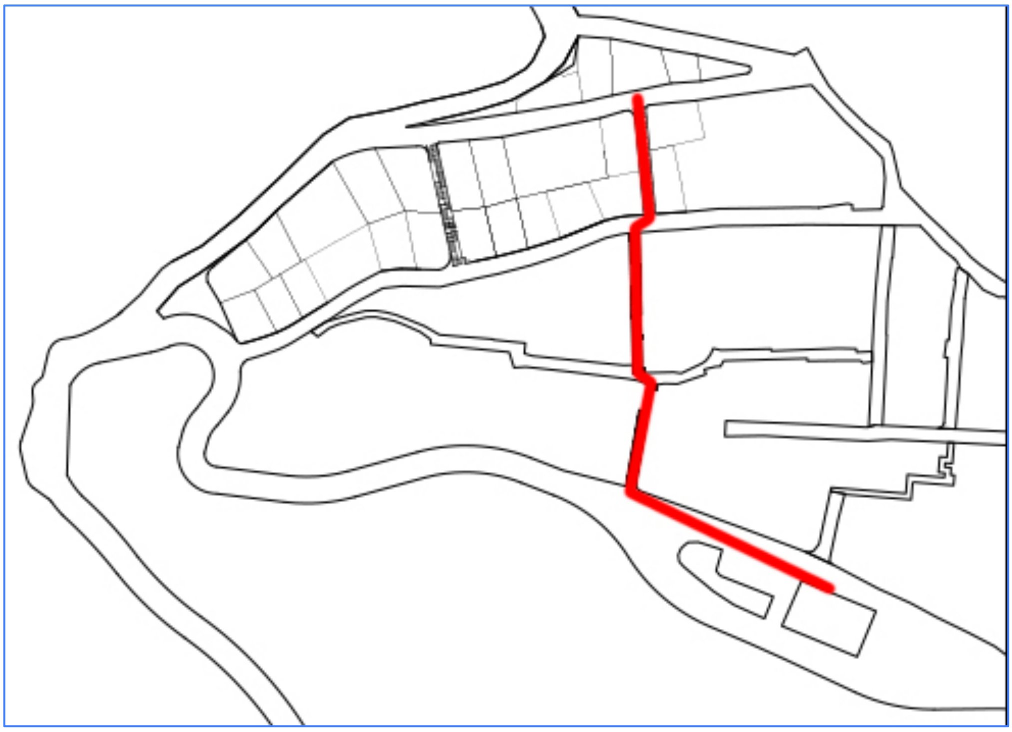


Figure 5-1 Evacuation practice path to be simulated

When looking at the results from group 1 in Figure 5-2 it can be seen that the time until the first person reaches the safe area is only 214 seconds. The evacuation flow was constant throughout the entire practice.

In the 2nd group, all occupants evacuated in a compact group. The time until the first person evacuated was longer than group 1, at 263 seconds. And in the 3rd group, the first person evacuates at 480 seconds.

5.2 Quantitative analysis of the evacuation simulation

In the following two sections the evolution of the evacuation is studied based on the experimental data and the simulations.

Figure 5-2 present the time when the group of participants evacuated the area affected. The figure also shows the proportion of the total evacuated people with respect to time.

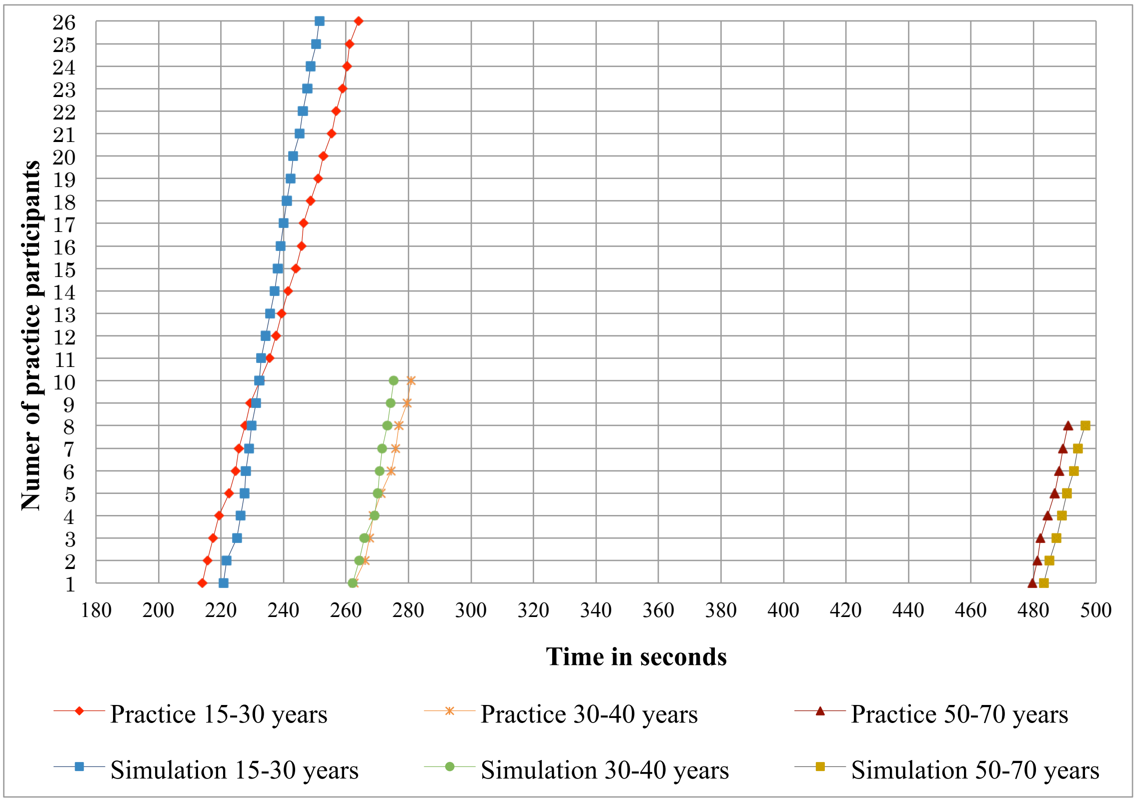


Figure 5-2 Comparison - Evacuation times of each occupant of every group and the proportion of evacuated occupants with respect to time

Looking at figure 5-2 the following can be noticed:

- The time from the evacuation starts when the first person reaches the safe area which is shown at the lower left corner of the figure (where all lines start). Depending on the path characteristics this includes distance and walking in slope plane and on stairs.
- The slope of the data points (each point indicates an agent reaching the safe area) indicates the speed of the evacuation. A steep slope indicates a high flow.
- The jumps or horizontal gaps show pauses in the evacuation. The gaps are delays, which can be related to the long travel distances or obstacles, such as other agents trying to use the same stairs.
- The time of the last person exiting the area is shown at the top, where 100% of the occupants evacuated the area.

In the following the evacuation procedure of the neighborhood evacuation is analyzed.

Group 1

When looking at the results from group 1 in figure 5-2 it can be seen that the time until the first person reaches the safe area is only 221 seconds. The evacuation flow was constant throughout the whole practice.

Group 2

When looking at the results from group 2 in figure 5-2 it can be seen that all occupants evacuate in one group. The time until the first person evacuated was longer than for group 1 being 263 seconds.

Group 3

When looking at the results for group 3 in figure 5-2 it can be seen that the time until the first person evacuates is 483 seconds.

5.3 Quantitative results from the simulations

During the simulations evacuees walked mostly following each other as a result of the use of the same free speed originating from the group. All agents started and finished the movement in the same location as the participants in the practice.
Furthermore, not much congestion occurred to modify the walking patterns.
Because of the velocity input data, evacuees walked slower on the stairs than on the flat routes and performed this without overtaking. This kept the order and the distances of the evacuees in the travelling queue almost constant during the evacuations.

5.3.1 Group 1 – 15 to 30 years old

The simulated outflow of people was continuous as observed in the practice, nevertheless we can see the simulation outflow to be steeper than the practice one.
Overlapping of outflow occurred over the 232 seconds. This happened because the simulated speeds on the stairs were continuous and people walked almost in a perfect queue flowing each other during the evacuation. The averaged 0.75m/s going down the stairs was much higher than the experimental values and the simulated outflows were much lower than the experimental (1.18 pers/s against 1.93 pers/s) (Figure 5-3).

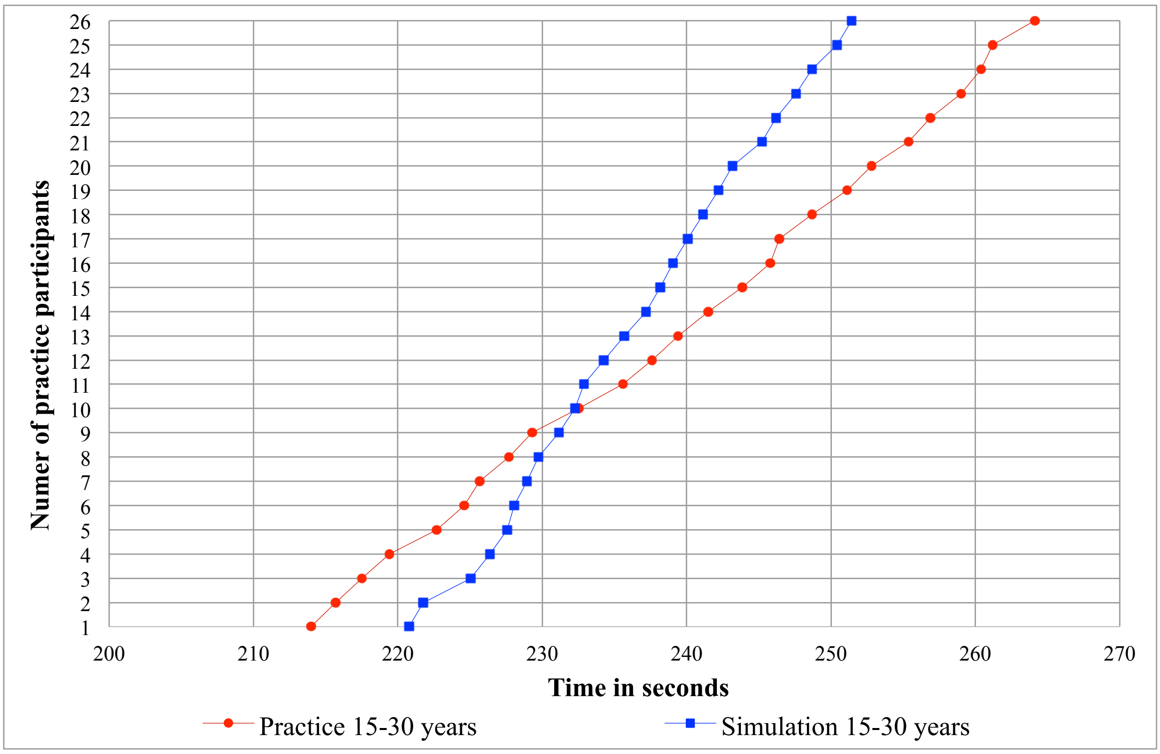


Figure 5-3 Distribution of individual evacuation times in group 1 simulations

This overlapping happened because in the practice the group started the exercise with more eagerness and focus about the goal, which was to get to the safe area. Enthusiasm decreased around halfway through the practice.

5.3.2 Group 2 – 30 to 40 years old

The evacuation time of the first evacuee matched the experimental value pretty well (0.1%) indicating that the average speeds in the evacuation path were properly simulated.

Until the halfway point during the evacuation the overflow is similar to the practice one. However, the movement velocity remained continuous until the end of the simulation. On the other hand the last half of the practice participants slowed down their velocity. As Group 1, participants decreased their enthusiasm when close to finishing the practice and they got apart and therefore a different evacuation time was obtained for the last evacuee (error of -2%) (Figure 5-4).

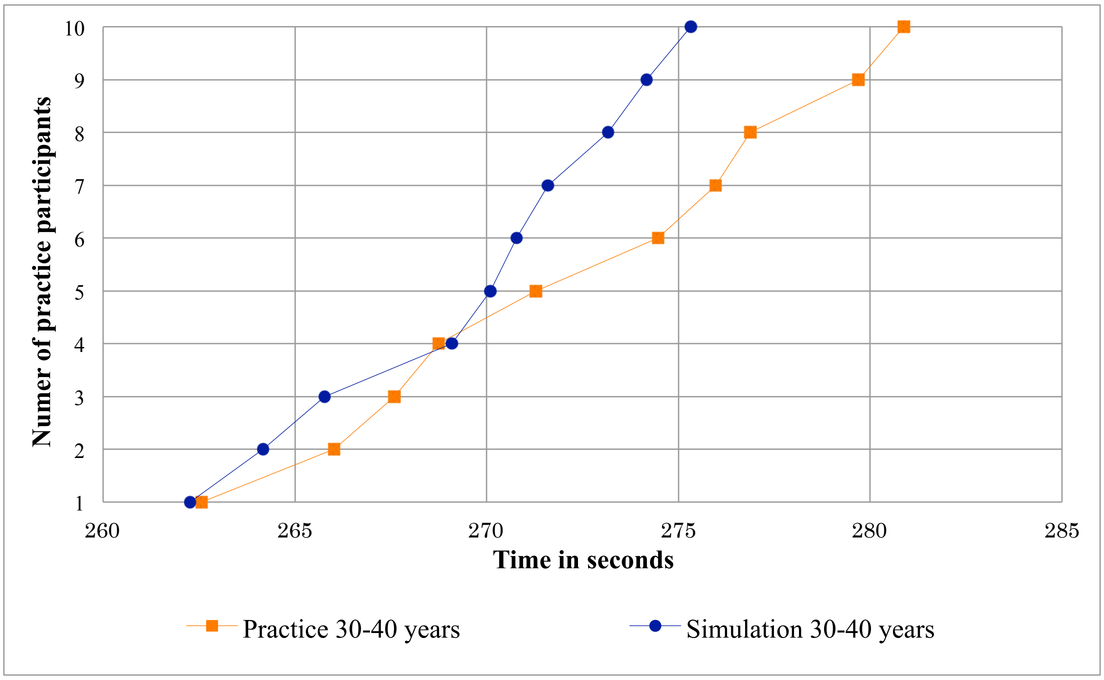


Figure 5-4 Distribution of individual evacuation times in group 2 simulations

5.3.3 Group 3 – 50 to 70 years old

The simulations of the third group were very similar to the process observed in the practice.

Fig. 5-5 shows that the simulated and experimental outflows were very similar in shape, around 1.60 pers/s.

In this experiment no stops occurred during the evacuation process that could delay the movement of people. Also in the simulations the three groups completed the evacuation practice at significantly different moments and presented two distinct outflows.

No dedicated model parameters for disabled people were presented, and the parameters from calibrations using data with a heterogeneous population composed of healthy adults were applied. This is an important aspect that needs further investigation.

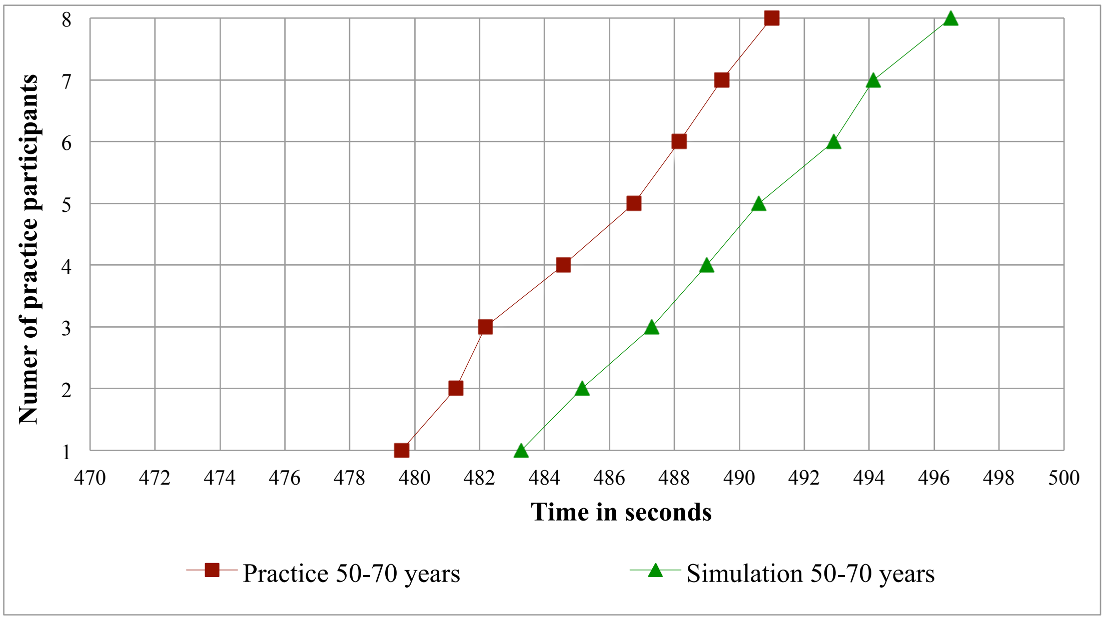


Figure 5-5 Distribution of individual evacuation times in group 3 simulations

The slopes in figure 5-4 with both evacuation times for group 2 showed a satisfactory agreement for the purpose of this investigation, but the same was not found in Group 1 and Group 3 simulations.

This comparison showed a good match between simulations and experiments. Although the above comparison would not be enough to server as a validity check, we concluded that Pathfinder simulated actual walking situations satisfactorily.
We compared two cases to show the differences between a planned evacuation and one with no guidance.

5.4 Simulation of the current situation and analysis

The simulation area is a simplified 3D model of “Cinco Dedos” neighborhood, where the agents had to find their way to the already selected exit, which in reality is a determined safe area selected for the evacuation practice. The results of the evacuation time of the two different approaches mentioned before are summarized in Figure 5-6

The agent based evacuation simulation software in both approaches selected the quickest path for a fast evacuation. People followed the closest exit path, as it would be expected in a real evacuation scenario.
Some parts of the sets of stairs present straight portions where faster agents generated a second flowrate, nevertheless, they got jammed as soon as the stairs changed direction with other agents following a single flow from the start of the stairs. This showed that the configurations of the stairs are not suitable for more than one continuous flowrate even when the slowest agent determines the flow velocity.

There is no significant difference between the results given by Case 1 (software simulation run) and Case 2 (recommended one), which is due to the distribution and the geographic conformation of the studied area.

This comparison is a sample of an agent-based software application for education and awareness among a community’s inhabitants, in which they do not trust government disaster programs and are not interested in being a part of such evacuation practices and drills.

5.4.1 Evacuation time

In case 1, agent-based evacuation simulation software selected the quickest path for fast evacuation. Participants followed the closest exit path as would be expected in a real evacuation.

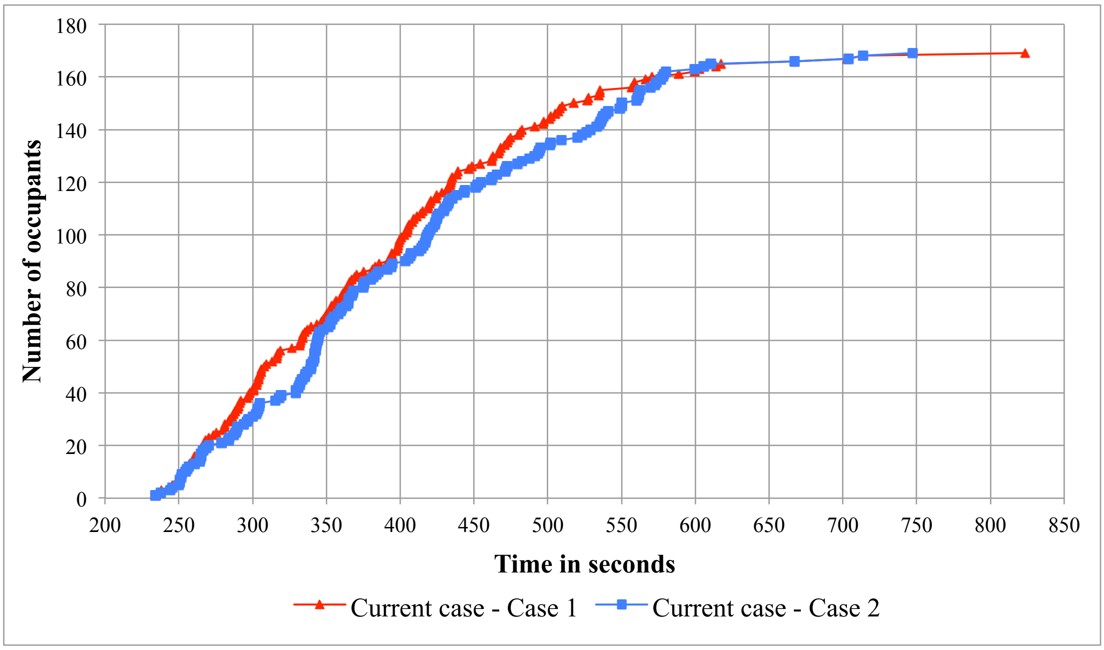


Figure 5-6 Evacuation time for cases 1 and 2 for current situation

In case 2, agents followed predefined rules in which their evacuation paths were divided by block. Agents from block A evacuated through flat streets and agents from block B evacuated over stairs as a principal way of evacuation (Figure 5-6).

Of the total number of persons evacuating the area, the percentage of agents using stairs decreased from 79% (case 1) to 57%, and 49 agents followed a different evacuation flow from those in case 1.

We understand that case 2 is not the fastest path and the distance is longer, but the path for reaching the safe area is a flat, wide and homogeneous avenue.

In these singular circumstances, no significant difference occurred between the results of evacuation times for cases 1 and 2. This is due to the distribution and geographic conformation of the studied area. Even so, case 2 gave us more positive results related to evacuation and jam time than case 1 did.

5.4.2 Jam time

Here we introduce the importance of collecting jam time data from simulation.
The time agents spent without moving is considerably longer for case 1 because of agent accumulation at bottlenecks on stairs being greater. More agents in case 1 got in jams trying to walk over narrow stairs. Some parts of stairs presented straight portions where faster agents generated a second flow rate, but they jammed with other agents following a single flow as soon as stairs changed direction.

In case 2, fewer agents evacuated toward stairs, creating less agent agglomeration so that overflow was more fluid and continuous.

The results of the total current jamming time are summarized in Fig. 5-7. There is little difference between the values of the results as in the previous case. This is due the distance and the different type of path. In the recommended path (Case 2) there are no stairs to climb down for 57% of the total amount of people evacuating the area. In this individual case where there is no faster path, 49 people follow a different flow from the agent based evacuation simulation Case 1, traveling a longer distance. However, the path is flat, wide and homogeneous as they follow an avenue to reach the safe zone. Those results are confirmed by the time in jam and the total evacuation time.

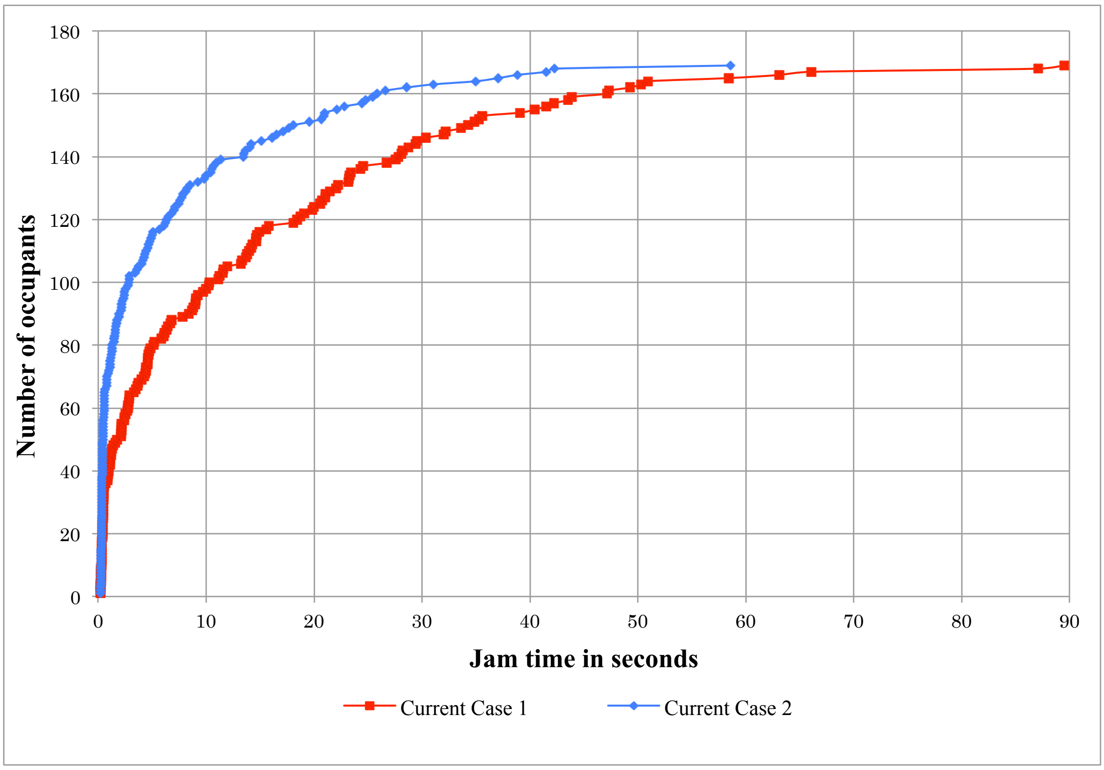


Figure 5-7 Jam time for cases 1 and 2 for current situation

5.5 Simulation in Future Projection

5.5.1 Evacuation Time for future projection

The same number of persons from the study area was evacuated in both cases. When comparing the evacuation efficiency of the two scenarios on a given expected hazardous occurrence in a determined period of time, e.g., time 1 in Figure 5-8, we may believe case 2 is more effective because it evacuated more persons than case 1 before the hazardous event happened. The same reason is applicable in concluding that case 2 is a better evacuation plan in any expected occurrence time. This work is based on group performance and behavior, so the objective of minimizing total evacuation time is preferable to minimizing maximum individual evacuation times for application to any evacuation plan or program.

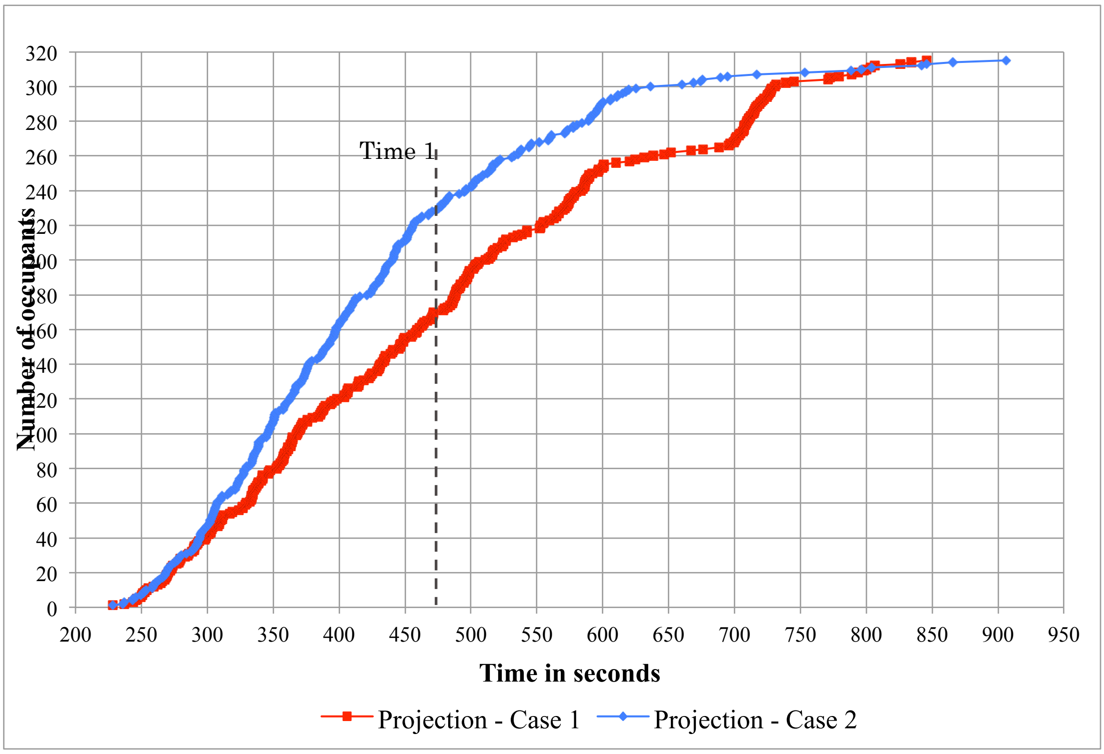


Figure 5-8 Evacuation time for cases 1 and 2 for future projection

5.5.2. Jam time for future projection

In the case of projected simulation, the most relevant result is that under conditions where an evacuation plan is applied as in case 2, the amount of time evacuees spend without egress (jam time) decreased 67% (Figure 5-9).

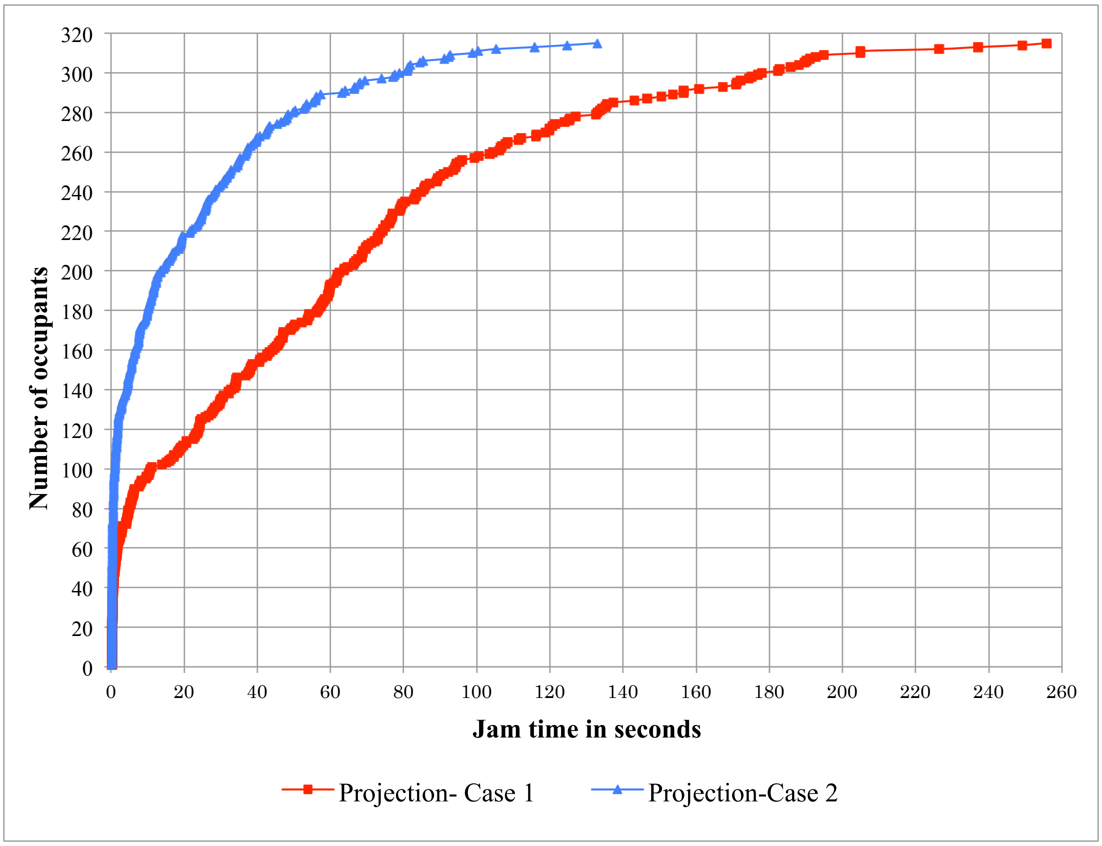


Figure 5-9 Jam time for cases 1 and 2 for future projection

5.6 Further Studies

Further investigations and more data are needed to determine if the model needs to be newly calibrated to handle the characteristics of the evacuation paths.

Furthermore, it needs to be investigated how to handle stairs characteristics such as the configuration and that there are no possibilities to change the situation. Reconsidering the evacuation plan and technical assistance is relevant as they can affect the evacuation times and make the process more predictable. More data and more simulations are needed.

CHAPTER 6: CONCLUSIONS

The aim of this research is to analyze the abilities of communities, levels of government and institutions to increase and improve resilience to landslide risks in areas where natural disasters have been increasing as much as their vulnerability because of the continued occupation of high risk zones. With this information, recommendation are made in order to motivate the implementation of a simple plan and strategy for an area of La Paz occupying the slopes of a mountain which creates risk for its inhabitants.

In order to create a proper strategy for these types of settlements it was important to analyze the ability or inability of a community to respond to the impact of a landslide. This is because even though disasters are the product of natural phenomena which cannot be controlled, it is the community's management of the land and immediate response to the disaster that is paramount in saving lives.

Landslides Risk Management in La Paz has improved over the last few years, however disasters are expected to continue to occur due urbanization in landslide prone areas, continued deforestation on slope areas, and increased precipitation caused by nature.

This work also recommends that better communication should be achieved between government bodies and the community.

It is important that the La Paz governance create strategies and tools to transmit knowledge to the community, but not in a traditional way where experts give instructions expecting that the community will follow without questioning the effectiveness of the plan.

Communities must be part of the plan in its creation and participate in the process of developing a culture of prevention in order to make their communities more resilient.

Empowering the community in such a way will generate a commitment whereby the government will introduce the community to the responsibility of finding improved ways to ensure their own safety, and at the same time prove to them that a post disaster response and recovery should not be the only method adopted to manage landslide risk.

An important finding was that in La Paz, people living in hazard areas, their community leaders and part of the governance underestimate or deny the risk and they do not take risk management in a serious and adequate way. For this reason, this work found that a bottom-up prevention strategy could be applied through disaster education for children in schools instead of using an top-bottom strategy where the community has no participation.

Disasters education is a very important part in the prevention of natural disasters and it has been applied in developed countries in the school curriculum as a formal subject with positive results when applied in early school years.
Elementary and secondary school have shown to be a good stage for the implementation of a formal disaster education. At these stages, education about disasters and how to prevent them may influence students' thinking and attitudes towards disasters. This behavior can affect students a lifetime and one relevant and important aspect for this work is that this knowledge can be transmitted to the students' families.

This thesis presents a strategy that can be applied and taught to school students and its application can show results in the short term. This pre disaster strategy is an early evacuation plan that can be applied in any disaster management program in La Paz.
In order to create evacuation knowledge and educate students about disasters to create more resilient communities, this investigation found that the use of simulations would be an effective way to generate consciousness specifically

throuhgh the creation of a compelling graphic tool for teaching people about early evacuation. It also provides students with opportunities to participate in virtual drills.

Its adverse characteristics make La Paz an appropriate scenario for this study. This city uses exterior public stairs as primary access to its inaccessible neighborhoods, whose peculiar configurations raised results not found in other research, most of which have been based on regular stairs either in tall buildings or in public urban spaces. Irregular non-continuous exterior stairs evacuation movement characteristics are not well understood. This study presented empirical data from evacuation practices involving movement over steep slopes on a high risk location.

The neighborhood called Cinco dedos which is located in Periferica District in the northeast part of La Paz was used to conduct semi-unannounced evacuation experiments.

The evacuation times were different in the 3 groups cases.

There was an age dependent behavior as people in the older age group were slower, while the groups in the younger age group seemed more focused and active.

The egress simulator model slightly under-predicted the total evacuation times in 2 out of 3 cases, meaning that the evacuation model should be adjusted in order to make predictions more accurate considering other additional factors and avoid overly optimistic estimations of evacuation times.

This approach also presented the possibility to evaluate the jam time of agents in the given study neighborhood configuration, considering possible evacuation route choices.

Two strategies have been presented in a combination of quickest, shortest and a more effective path.

The movement simulator generated a shortest distance for evacuation strategy, using a combination of parameters to select their current path to an exit or safe area.

After running the simulation with data taken from the practices, input as parameters, we could find the follow conclusions:

Even if the distance is longer, the evacuation time remains almost the same. That means that Jam time is less when there is a plan and order in the evacuation movement.

When there is a strategy, order and organization, for instance an evacuation plan, in a real situation the evacuation becomes under control and fluid. With this, there are fewer levels of stress and panic in people's behavior when walking to a safe area.

In an evacuation, people move at different velocities, however, the presence of stairs that do not allow people to overtake each other when ascending or descending them. The stairs width is not a parameter that controls the velocity of people evacuating them, however, the configuration of the stairs like the ones in this work can affect the movement of the people using them for evacuation. The velocities change based on the person in front. The velocity of people following the same path when evacuating will be related to the person in front of the line.

The flowrate is a parameter that surely depends on the width of the stair, but in the case of Cinco dedos the continuous change of direction of the stairs does not give evacuees enough space to create a second flow with a different velocity.

This difference shows that when an evacuation is planned, the movement of people will be fluid, and with this evacuees will feel more secure and safer allowing the community to respond better when an event happens.

The strategy we presented in this study may not be the best solution, but it could be one such solution because the model aims to contribute to better understanding of evacuation behavior and possible measures for improving evacuation performance.

6.1 Additional Research Needs

This work provides a basic understanding in human behavior related to evacuation. Additional research is needed to better understand other presented factors, including the following:

-A better understanding of movement and behavior of occupants moving on irregular stairs is required. This thesis presented a simple analysis of the time occupants take to arrive at a safe area.

-Additional data on movement speeds, particularly in various stair configurations are needed to better understand the important variables that impact stair movement speeds.

-Additional analysis of stair movement data to determine the best values and distributions for egress model inputs would facilitate modeling and help us to understand the additional data necessary to generate more accurate data.

- If physical impediment is present in certain conditions during evacuations, it will be important to understand its impact on evacuees' movement speeds and flow.

- Since all of the analyses in this work are based on simulated evacuations, additional research on the similarities or differences between simulation and real disaster evacuation needs to be analyzed.

- Although the primary focus of this report is on stair evacuation movement speed and the important stair design parameters that may impact this movement, human behavior also plays a key role in the overall evacuation timing. Thus, information on the timing prior to evacuees' movement on stairs should be included.

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ANNEX 1: **List of the 70 Neighborhoods Included In The Study**

#	Macrodistrict	Neighborhood
1	Centro	Santa Barbara
2	Centro	Miraflores Bajo
3	Centro	Rivera Izquierda Río Orkojahuira
4	Centro	Rivera Derecha Río Choqueyapu
5	Cotahuma	Playa Verde
6	Cotahuma	Adela Zamudio
7	Cotahuma	Cancha Fígaro
8	Cotahuma	Llojeta, Final Almaráz
9	Cotahuma	Julio Téllez final
10	Cotahuma	Francisco Bedregal
11	Cotahuma	San Miguel de Alpacoma
12	Cotahuma	Relleno Sanitario Kantutani
13	Cotahuma	Tacagua
14	Cotahuma	Cotahuma
15	Max Paredes	San Francisco
16	Max Paredes	Particirca
17	Max Paredes	Alto Ciudadela
18	Max Paredes	Alto San Pedro
19	Max Paredes	3 de mayo
20	Max Paredes	San Lorenzo
21	Max Paredes	San Sebastian
22	Max Paredes	San Martin
23	Max Paredes	Rincon La Portada
24	Max Paredes	Alto Pura Pura
25	Periferica	Limanipata
26	Periferica	Alto Plan Autopista
27	Periferica	Plaza Litoral
28	Periferica	Agua de la vida
29	Periferica	Las Nieves
30	Periferica	Señor de Exaltacíon
31	Periferica	3 de Mayo
32	Periferica	Rossani
33	Periferica	El Rosal
34	Periferica	Union Huaychani
35	San Antonio	San Simon
36	San Antonio	Catalina
37	San Antonio	márgenes Der Izq del Río Irpavi
38	San Antonio	Villa San Antonio
39	San Antonio	IV Centenario
40	San Antonio	German Jordán
41	San Antonio	Octavio Campero
42	San Antonio	San Isidro Alto
43	San Antonio	Valle de las Flores
44	San Antonio	Cervecería
45	San Antonio	Metropolitana
46	San Antonio	Bajo Salomé Ladera Este
47	San Antonio	Kupini
48	San Antonio	Plaqueta Juan sin Miedo
49	San Antonio	Tejajahuira
50	San Antonio	Valle Hermoso Villa Copacabana
51	Sur	Ciudadela Stronguista –Norte
52	Sur	23 de Marzo - Achumani
53	Sur	Las Carmelitas
54	Sur	Comphia Huayllani
55	Sur	Flor de Irpavi
56	Sur	Los Lirios Pedregal
57	Sur	Cota Cota desde la calle 32 a 35
58	Sur	Cota Cota desde la calle 25 a 28
59	Sur	Santa Fe de Kessini
60	Sur	Calle 23 Bella Vista - Ventilla
61	Sur	Calle 24 de Junio - Seguencoma Alto
62	Sur	Calle 29 Las Lomas - Achumani
63	Sur	Calle 20 Bella Vista
64	Mallasa	Relleno Sanitario – Mallasa
65	Mallasa	Margenes del Río Achocalla
66	Mallasa	Margenes del Río La Paz
67	Mallasa	Jupapina
68	Mallasa	Mallasilla
69	Mallasa	Providencia
70	Mallasa	Vecinos de Aranjuez

ANNEX 2: **Community Surveys (Translation from Spanish)**

Survey no: ___________________________________

Zone: ____________________________

Neighborhood: ________________________________

Name(s) of interviewed:

____

What is your position in your community organization?

How old are you?

Which was the highest level of education you received?

a. Primary

b. Secondary

c. University

d. none

Did your work last week?

a. Yes

b. No

What was your main activity about your work these days?

This neighborhood has…

a. Radio signal

b. TV signal

c. Internet service

d. Phone connection, mobile connection

How do you dispose the garbage

a. Public container

b. Public picking up trucks

c. Throw it on the street

d. Throw it into the river

e. Burn it

f. Other

(Based on survey created by Cruz (2010))

What is the status of legalization of your neighborhood?
a. Legalized
b. In process of legalization
c. Not legalized
d. Other:_______________

(If it is legalized)
When it was legalized?______________________________

(If it was legalized less than 5 years ago or if it is in process of legalization)
How long did the legalization process take or is taking?

(If it took more than a year)
Why did the process take so long?

(If it is not legalized)
Why is the neighborhood not legalized?

What basic services does your neighborhood have and what is the coverage?

Basic service	Yes	No	Coverage: total or partial
Light			
Drinking water			
Telephone			
Sewerage			
Access roads Transport			

Can you locate in the attached map of your neighborhood the following thing?

Zones and places to locate	Yes	No
Neighborhood limits		
Unsafe zones due to antropic factors:		
- Crime and violence zones		
- High contamination zones		
- Traffic accident zones		
- Housing on slope areas		
Unsafe zones for natural factors:		
- Landslide zones		
- Flooding zones		
Safe zones		
- Community police unit		
- Communal house		
- Shelter		
- Other:		

(If he/she identified any natural event)
From the events you identified, which ones are the most recurrent?

Have you heard about risks and hazards that affect your neighborhood?
a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

And about landslides and floods?
a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

(If he/she answer affirmative)
What have you heard?

How did you hear it?

Does the community receives or has received talks about hazards and risks in the last 2 years?
a. Yes
b. No

(If yes)
With what frequency have your received this talks?

Who has participated in the talks and what have been the themes?

Who has given the talk?

In this talks participate:
a. The entire community
b. A big part
c. A small part
d. A minority

Who are the ones that participate the most?
a. Children
b. Youth
c. Adults
d. Elderly
e. Men
f. Women
g. Others:

Do the members of the community get together?
a. Yes
b. No

(If yes)
Who gets together?

How frequently?

What are the main topics discussed in the meetings?

Do you consider that the neighborhood has been taken into account by the municipality in themes related with the city development?

a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never.
Why?

Do you think that the neighborhood knows and complies the norms and ordinances of land occupation and construction?

a. Yes they know and the majority complies
b. Yes they know and a few comply
c. Yes they know but they do not comply
d. They do not know and do not comply
Why?

Are there institutions that control the compliance of security and construction norms?

a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

(If yes)
Who controls and how do they play their role?

When the members of the neighborhood construct any infrastructure, do they take into account landslide risk and flooding?
a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

(If yes)
In what way do they consider it?

(If no)
Why don't they consider it?

Have there been works to protect your neighborhood from landslides?
a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

(If yes)
What works?

Who has done it?

What is your neighborhood doing to take care and protect the environment, the basins and the slopes?

What are the most important improvements and achievements that your neighborhood has accomplished to be safer?

How does your neighborhood related with the municipality? Are the actions coordinated to improve the neighborhood? How are those actions coordinated?

When there is an emergency, what emergency organisms are or would be the ones that arrive first?

In case of a landslide or flood, is the community prepared and do they know what to do?
a. Yes, the majority
b. Yes, some
c. Yes, a few
d. No

(If yes)
Explain what would the community do, where would they go, who would be in charge of each activity?

Does an early warning system or a community alarm exist?
a. Yes
b. No

(If yes)
What is the alert about?

For what situations is it used?

Do you perform simulations?
a. Yes, all the time.
b. Sometimes
c. Few times
d. Rarely
e. No, never

(If yes)
What type of simulations, how often and who are promoting it?

If there is an emergency or disaster in your neighborhood, what type of support have the affected families receive?

After an event, such as a landslide, what did you as a community did to recover?

Do you think that people living in risk zones would be willing to move to safer areas?
a. Yes
b. No
c. Maybe

Why or under what conditions?

Does the community feel safe of dangers such as landslides, heavy rain or floods?
Why?

Danger	Yes	No	Why?
Landslides			
Floods			
Heavy rain			
Accidents			

(If they answer that they feel safe)
Why do they feel safe?

(If they answer that they do not feel safe)
How do you think the community can improve this unsafe situation?

ANNEX 3 **Survey for students (Translation from Spanish)**

Where do you live?

How do you come to school?

What does the word ‘disaster’ mean to you?

Do you know what a landslide is?

Yes or No

Yes. (Very well/ Yes, good enough/ Yes, some things/Only few things/Almost nothing/ Not at all).

If yes: Where did you learn about it?

What did you learn?

Do you know what to do if a landslide happened when you are home?

Yes or No

Yes. (Very well/ Yes, good enough/ Yes, some things/Only few things/Almost nothing/ Not at all).

If it happened during the day/night?

Does any member of your family know about landslides?

Where did he/she learn from?

How many members you family has?

Did you learn about disasters in school?

When?

Who taught you?

Did you understand what they taught you?

So now, you know what to do in case of a landslide?

If there is a disaster during school hours is there a pre-designed area to gather students outside the school building?

What would you do?

What is the first thing you would do?

Would you like to learn about disasters?

What would you like to learn?

Would you like to learn what to do if a landslide happens near your house?

Would you like your family member to know what to do?

Do you think you can teach them what you learn in school?

Have you heard about risks and hazards that affect your neighborhood?

Yes or No

And about landslides and floods?

Yes or No

If yes:
What have you heard?
How did you hear it?
Does the community receives or has received talks about hazards and risks in the last 2 years?
Yes or No, I don’t know
If yes:
With what frequency have your received this talks?
Who has participated in the talks and what have been the themes?
Who has given the talk? Themes: