Instituto Tecnológico de Costa Rica
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Analysis of the existing information of La Carpio informal settlement, Roble Norte sector, to create the basis for future research in fire safety.

Proyecto final de graduación para optar por el grado de
Licenciatura en Ingeniería en Construcción

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Analysis of the existing information of La Carpio informal settlement, Roble Norte sector, to create the basis for future research in fire safety

Abstract

In Costa Rica, more than 220,000 people live in informal settlements, under a situation of vulnerability and risk (INEC, 2011). There is a global tendency for population growth, this growth will not be distributed equally geographically, it will mostly affect low to low-middle income countries (UN, 2018). This population rising will foster the increase of people inhabiting informal settlements or will trigger the creation of new ones. Fire risk is another subject affecting these kinds of settlements, proper investigation regarding fire safety in informal settlements has been disregarded by the Costa Rican researchers. This research focusses its attention in La Carpio informal settlement, taking as a sample the Roble Norte sector. It collects the available data regarding quantitative and qualitative aspects of the settlement, also gathers sociodemographic data and fire records with the intention of performing the data and fire risk analysis for this community. This document has the main intention of being a basis for future investigation, boosting researchers to get involved in topics related to fire safety or update databases which help decisions making for problem-solving in informal communities.

Keywords: Informal settlements, Fire safety, La Carpio, Databases, Fire risk.

Resumen

En Costa Rica, más de 220,000 personas viven en asentamientos informales, en situación de vulnerabilidad y riesgo (INEC, 2011). Existe una tendencia global de crecimiento poblacional, este crecimiento no será distribuido de manera equitativa geográficamente, ya que los países de ingresos bajos a medio bajos serán los más afectados (UN, 2018). Este crecimiento poblacional fomentará el aumento de personas habitando en asentamientos informales o desencadenará la creación de nuevos asentamientos. El riesgo de incendios es otro tema afectando estas comunidades, investigación relacionada con seguridad contra incendios en asentamientos informales ha sido ignorado por los investigadores costarricenses. Por lo anterior, esta investigación centra su atención en el asentamiento informal La Carpio, tomando a su vez como muestra el sector Roble Norte. Aquí se recolectan los datos disponibles en relación con características cuantitativas y cualitativas del asentamiento, además información sociodemográfica y registros de incendio con la intención de realizar el análisis de datos y de riesgo de incendios de esta comunidad. Este documento tiene como principal intención ser una base para futuras investigaciones, impulsando a los investigadores a involucrarse con temas relacionados con la seguridad contra incendios o la actualización de bases de datos, que puedan ayudar a tomar decisiones para la resolución de problemas en comunidades informales.

Palabras clave: Asentamientos informales, Seguridad contra incendios, La Carpio, Bases de datos, Riesgo de incendio.

Analysis of the existing information of La Carpio informal settlement, Roble Norte sector, to create the basis for future research in fire safety

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Final graduation project to opt for the degree of
Bachelor in Construction Engineering

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INSTITUTO TECNOLÓGICO DE COSTA RICA
ESCUELA DE INGENIERÍA EN CONSTRUCCIÓN

Dedication

To my father, the man who has loved me the most in life

Acknowledgments

To God, for giving me all the amazing things of my life.

To my mom, for bravely supporting me in every decision I make, for all the advice and love she gives me.

To my older brother, for always encourage me to do whatever I want, and even for the things that I do not want to do.

To my younger brother, for making me laugh in every moment, for strongly believe in me, and for his infinite patience.

To my professor John Adam Gales for all his help and for teaching me even when I did not realize I was learning something. Also, to all his team from York University, for being so welcoming and supportive with me.

To Chloe Jeanneret my mentor, reviewer, and friend. For all the support, good moments and company she gave me while I stayed in Canada.

To all my friends, who always stayed with me, for our tears and laughs together. Also, for helping me to conclude this step and supporting me in the hardest moments of my life.

To the Emerging Leaders in the Americas Program (ELAP) for the funding that made possible the completion of this work and my research exchange at York University, Toronto, Canada.

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Acronyms

AyA	Acueductos y Alcantarillados (Aqueducts and Sewers)
BANHVI	Banco Hipotecario de la Vivienda (Mortgage Housing Bank)
CCSS	Caja Costarricense del Seguro Social (Costa Rican Social Security)
CFIA	Colegio Federado de Ingenieros y Arquitectos de Costa Rica (Federated College of Engineers and Architects of Costa Rica)
CLACDS	Centro Latinoamericano para la Competitividad y el Desarrollo Sostenible (Latin American Center for Competitiveness and Sustainable Development)
CODECA	Consejo de Desarrollo Comunal de La Carpio (La Carpio Community Development Council)
CNE	Comisión Nacional de Emergencias (National Emergency Commission)
CNFL	Compañía Nacional de Fuerza y Luz (National Force and Light Company)
FUPROVI	Fundación Promotora de Vivienda (Housing Promotion Foundation)
GAM	Gran Área Metropolitana (Greater Metropolitan Area)
ICE	Instituto Costarricense de Electricidad (Costa Rican Institute of Electricity)
IDEB	Infraestructura de Datos Espaciales de Bomberos (Firefighters Spatial Data Infrastructure)
IMAS	Instituto Mixto de Ayuda Social (Institute of Social Assistance)
INEC	Instituto Nacional de Estadísticas y Censos (National Institute of Statistics and Census)
INVU	Instituto Nacional de Vivienda y Urbanismo (National Institute of housing and town planning)
ITCR	Instituto Tecnológico de Costa Rica (Costa Rica Institute of Technology)
MEP	Ministerio de Educación Pública (Ministry of Public Education)
MIVAH	Ministerio de Vivienda y Asentamientos Humanos (Ministry of Housing and Human Settlements)
MSJ	Municipalidad de San José (San Jose Municipality)
OCO	Oficina de Comunicaciones Operativas (Office of Operative Communications)
SFNV	Sistema Financiero Nacional de Vivienda (National Housing Financial System)
Sifais	Sistema integral de formación artística para inclusión social (Integrated system for artistic training and social inclusion)
SINVI	Sistema de Identificación de viviendas (Housing identification system)
UN	United Nations (Organización de las Naciones Unidas)
UNA	Universidad Nacional de Costa Rica (Costa Rica National University)
WHO	World Health Organization (Organización Mundial de la Salud)

Preface

Decent housing and people's well-being is crucial in our growth as a society. Unfortunately, not all people have the same living conditions. In Costa Rica according to INEC in 2011 informal settlements sheltered 4.78% of the whole population. As the country's population grows, so the inhabitants of these communities do. Therefore, a solution for the disappearance or the improvement of informal settlements is needed. Poverty, vulnerability and social issues are particular features of the population inhabiting these zones. A joined effort between the government and the community members must be done in order to enhance these informal communities.

The main objective of this project was to collect information of La Carpio informal settlement and the Roble Norte sector, one of the nine sectors of La Carpio, to analyze the existing information and determine what is available and what is not. Through the development of this investigation, the author realized there is a lack of data and research, therefore this document turned into exploratory research. It will show the reader the existing information and the features of the same, evidencing at the same time the information lacking and the absence of data updating. Besides, the research will allow analyzing how difficult is to draw accurate conclusions or establish solutions for the several problems this zone has.

The first intention of this research was to collect information to draw solutions regarding fire safety in La Carpio, but it was found out a huge gap of knowledge, impeding to develop this objective. Thus, it was necessary to re-address the research into the analysis of databases to determine what information is available for its study and which entity should gather it. One of the intentions was to perform a data foundation for problem-solving but, the data is antique from 10 years before or more, and it cannot be used in this way.

This research describes the current situation in Costa Rica regarding fire issues and contextualizes it in relation to informal settlements. It gathers qualitative and quantitative features of La Carpio with the intention of described what is settled there, and the social characteristics of the population who inhabits this settlement. As mentioned before, there is a lack of information, thus, several data are unknown and pending its collection. Finally, it was compiled information about past experiences of other countries when applying measurements related to fire safety in their informal communities, this could help to find a solution for the Costa Rican problem.

It is appreciated the support given by the members of the Fire Department of Costa Rica. Especially to Miguel Dionisio Araya Álvarez, member of the Fire Department Engineering Unit, for all the help, advice and attention during the development of this research.

Executive summary

This project was developed in coordination with the Fire Department of Costa Rica, with the purpose to establish the basis for proposing future solutions for the fire issue in informal settlements of the country. This project intends to make a bind between the Costa Rica Institute of Technology and the Fire Department of Costa Rica, for future collaboration and development of research and projects, regarding fire themes, that could benefit both institutions.

This document shows all the existent and available information of La Carpio and the Roble Norte sector. To gather the information shown herein, several public institutions were consulted. For collecting the perspectives of the Fire Department of Costa Rica members, it was performed and interview with several firefighters from different stations. Knowing the judgment of the main people involved with fire issues is vital to the future development of research and projects. Also, it was deemed the opinion of a member of the Ministry of Housing and Human Settlements, in order to grasp their criteria regarding the informal settlements' problems, and the possible solutions they are proposing to this affair. Additionally, it was performed a meeting with members of the San Jose Municipality, which gave to the author vector files with information gathered of this settlement.

For collecting the visual information displayed, it was requested the support of the Mata Redonda police department in La Uruca, which granted permission and assigned two officials as escorts of the author. The pictures were focused on Roble Norte sector, having this zone high likelihood of fire occurrence, and other disasters as landslides, and structural collapses. This due to the conditions and terrain features the sector has, which can be observed in further sections. Also, the La Carpio health center was visited for information gathering, thus, it was needed to ask for permission in person.

With all the information exhibited herein, some recommendations were proposed with the purpose of continuing with the development of this research line. It is a novel topic that could bring benefits to many people, mainly the ones who inhabit in informal settlements. The objective of beginning this research line is in the future to reach a holistic solution for this population which includes, housing solutions, fire safety, economic growth, and strengthen social deficiencies. This research will mark the beginning to achieve this goal.

Other countries have implemented tailored solutions for their informal settlements' matters. This investigation line seeks to find in the future the measures that can better fit with the Costa Rican problems. The examples given by other countries can be used as a guideline that can direct us in finding the best solution. At the end of this document, some recommendations are given in order to define future steps that must be followed to achieve this objective.

1. Introduction

Nowadays the worldwide population growth is rising, it is expected for 2050 the population increase by 13% (UN,2018). As this phenomenon affects the world it also affects Costa Rica. In San Jose, access to better opportunities are causing the migration from the countryside to urban areas. This situation joined to poverty and limited opportunities to acquire a house are promoting the creation of informal settlements or the evolving and growing of the existing ones. This evolution can be observed in the creation of new informal houses of several floors, heightening the probability of suffering structural collapses.

Usually, the population living in informal settlements are poor or extremely poor, therefore, they commonly do not have tenure over the land or house they inhabit. In addition to this, the houses they build do not have planning or logical distribution, and the construction materials used are usually from low quality. Due to poverty, migration and population growth, the challenges within the informal settlements have been becoming severe throughout the years. Also, there is a global tendency in the informal settlements concerning the evolution of housing, where homes are upgraded instead of re-built or relocate the families, to achieve the disappearance of the informal settlement.

The conditions which under people live are in some cases regrettable, the health risk to which they are exposed is worrying. For instance, in the Roble Norte sector, alleys are characterized by usually having garbage stacked in their entrance. Even having the most-followed garbage collection services, the conditions persist. The general distribution of the informal settlement in study is disordered. In the Roble Norte sector, the alleys are narrow and irregular, being difficult to transit, even more for people with disabilities.

On April 13th, 2019, a fire in La Carpio left a death toll of seven people and eleven people affected. This fire is meaningful for this investigation since it raises awareness in the Costa Rican population about the problems the people inhabiting informal settlements are facing. This event augmented the attention of the authorities, which also gave special support to perform this research.

When a fire occurs in this settlement, besides the poor construction materials, the narrow alleys, and the garbage piles, another factor affecting the fire spreading is the proximity among the houses. The width of the paths in deeper sectors of Roble Norte, as Las Gradas, sometimes reaches widths of approximately 70 cm. In this zone, the paths have high slopes, since they are located at the bank of a river, thus wooden, soil or concrete steps can be found. Related to the slopes, the wind speed in this specific zone is higher, affecting the fire dynamics and making it easier for the fire spread.

1.1 Problem statement and justification

The overpopulation issue is becoming into a worldwide matter of importance. As all the cities around the world grow, so does the Great Metropolitan Area (GAM) of Costa Rica. This therefore also affects the neighborhoods that compose it. The GAM accommodates more than the 50% of the Costa Rican population in less than 4% of the national territory. It also contains 56% of the informal houses and 71% of the informal settlements of the country. These settlements depicts 51% of the housing deficit of the cantons that compose the GAM (CCC, 2018). The population increase is leading these neighborhoods to even more overcrowding. In the informal settlements, this overpopulation issue is boosting the evolution of the housing conditions, triggering the construction of taller buildings and enhancing the danger of living in these places.

One of the most important problems that the people living in informal settlements undergo is the constant risk of a fire. In the last years, the amount of fires occurring in informal settlements in Costa Rica has been having a fluctuant tendency, however, this issue could lead to a higher risk of losing lives or belongings. This is worsened by the lack of research related to fire safety that can be applied effectively in these specific kind of settlements. The main intention of this project is to start to define the basis and reduce the knowledge gap regarding this subject. Having no previous information, it is necessary to determine the first steps that should be followed to find a solution in the future.

Costa Rica has approximately 418 informal settlements (Censo 2011) distributed in the seven provinces of the country. This project focusses its attention in La Carpio and Roble Norte, a specific sector of this informal settlement. La Carpio originated in 1993 by an invasion of lands belonging to the Caja Costarricense del Seguro Social (CCSS, Costa Rican Social Security). It is located in the Uruca district that belongs to the San José canton, which is in the west of the San José province, the capital of the country (Sandoval, 2005). La Carpio houses a total of 19,035 inhabitants (Censo, 2011), and is surrounded by two rivers, with the Río Virilla in the north and the Río Torres in the south. As a result, the north and south sides of La Carpio have strong slopes and rugged topography.

Figure 1. La Carpio informal settlement
Source: Google Earth

La Carpio was selected for this project since it is the biggest and one of the most important informal settlements in the country. It therefore is the settlement which has the most complex issues. The Sistema de Identificación de Vivienda (SINVI, Housing Identification System) is an instrument developed by the MIVAH that allows the identification and classification of the settlements in precarious or slum conditions, with priority given according to the socio-habitational, feasibility and necessity context. The classification is made through the geographic prioritization of housing categories and it is assorted by deciles, where 1 means low priority and 10 high priority of attention. (MIVAH, n.d.). Performing a query into the SINVI system shows that La Uruca district is in the 10 decile, meaning that it is one of the districts which has the highest priority of attention due to the amount and conditions of their informal settlements.

La Carpio is divided into nine sectors called: San Vicente, ProDesarrollo, Central, Roble Norte, Roble Sur, Las Brisas, La Libertad, Pequeña Gran Ciudad, and María Auxiliadora. In order to develop this research, it was necessary to pick a sample settlement due to the extension and the short period of time available to perform the investigation. For this study, Roble Norte was selected since it is one of the sectors with the highest likelihood of fire occurrence according to the interviews performed to the Fire Brigades Stations. Furthermore, it has a population living under a high vulnerability condition due to the lack of decent housing, overcrowding, poverty and the constant threat of undergoing different disasters.

La Carpio is also undergoing changes related to the hierarchy of risks to which they were accustomed to in the past years. In the meeting carried out in San Jose Municipality, Oscar Núñez, a member of the Municipal Office of Disaster Risk Management, commented that the funding the Municipality used to spend in emergencies in La Carpio is now changing from floods to fires. In the years before 2019, the money was usually used to help the families that suffered losses by landslides or floods in the rainy season due to the absence of good sewage systems. Nuñez also commented that by July 2019, almost the total amount destined to emergencies for the rainy season was spent trying to help families overcome fire disasters. This means that the problem is getting worse and there is a real need for a solution.

Finally, the main reason to select this specific informal settlement, in addition to all the stated above, was the fire that occurred on April 13th, 2019. This fire affected two dwellings which were divided into several rooms that worked as residences for different families. This fire took the lives of seven people and left the survivors homeless. The author considers that one of the main duties of the engineers should be to work in favor of the people with greater needs, seeking to improve their lifestyles and having a key role in social responsibility issues.

1.2 Objectives

1.2.1 General objective

To analyze the existing information of La Carpio informal settlement and Roble Norte sector of La Carpio, regarding background, geography, sociodemographic data, and fire records, through field visits and data collection from different institutions to create the foundation for future research.

1.2.2 Specific objectives

1. To describe the current situation of the country regarding fire matters and contextualize it in relation to informal settlements.

2. To identify the qualitative and quantitative features of La Carpio and Roble Norte sector, which determine the risk of ignition or fire spread in the area.

3. To compile information related to applied measures in fire safety in informal settlements in the world, that could help to address future solutions for the Roble Norte issue.

1.3 Scope

This project emerges as an initiative to study fire safety in informal settlements, aiming to keep the population inhabiting them safe in case of fire. This research looks for the collection of all the information available about the informal settlement in study, in order to show the information to the stakeholders and aware them about the lack of data that could be useful to enhance the attention of fires or to decrease the occurrence of the same in informal settlements. Also, it looks to aware the population about the importance of having safety measures against fires. In the long-term, this project wants to establish tailored measures for these specific settlements, such as: raise awareness in the inhabiting population about the importance of fire prevention in their localities; propose techniques that enhance the response of the inhabitants during a fire and avoid interfering with the firefighters' procedures; establish actions that can ameliorate the recovery process and others. The outcome of this research is a document that gathers all the information collected through several institutions, that can help the Fire Department of Costa Rica to improve the way they manage fires in the informal settlement in study. Also to aware the community members of La Carpio about the risk under they are and encourage them to create fire brigades that could help the contention of future fires. Though this project is looking for arouse the awareness about the fire issues in all the informal settlements of Costa Rica, it was necessary to select a specific settlement to start the research, in this case, the Roble Norte sector of La Carpio.

The author understands the complexity and extension of the whole investigation line from this project, therefore, to contribute to achieving the objective, this document will be the beginning of the research line. The present document focuses its attention on looking for all the background information related to the subject, on the process of gathering and analyzing the information, and on the detection of the available and missing information of the selected zone. Moreover, information about the physical features of the case study will be collected through field visits, thus generating visual information. Finally, the last objective the document will cover is a comparison related to fire safety in informal settlements between several countries. This will allow to observe what solutions have been raised by other countries and to analyze if any could be applied to the Costa Rican issue. This could be helpful as a guide for future steps that must be established and followed to solve the problem. It must be noted that all the analysis and suggestions given in this document will be under the laws that govern the Costa Rican Republic.

This research focuses its attention on gathering information from the main stakeholders. The opinion of the population inhabiting the informal settlement was not collected since the fire events discussed in this research occurred recently, and the victims are still overcoming the catastrophe. Besides the associated risk for the information gathering in this settlement. The author deems it is too soon to inquire for information related to the past fire and it is preferred to give them space to surpass what happened. Another compelling reason is that, apparently, this fire was arson according to the fire report conducted by the Engineering Unit of the Fire Department of Costa Rica (2019). The investigations are still in progress but, knowing this, there is a motive for the population to avoid contributing information because they could be exposed to retaliation. For all those reasons, information gathering from the dwellers will be postponed.

1.4 Limitations

The research performed faced several limitations, mainly related to the existing knowledge gap as this is a new subject of investigation in the country. In fact, this document is the beginning of this research line. Below, two lists are shown: the first covers the general limitations and the second the limitations related to La Carpio informal settlement.

General Limitations

- There is a lack of information related to the topic background, informal settlements features, fire record data, demographic and socio-economic statistical data.
- The data collected from La Carpio and Roble Norte is outdated and incomplete. Information related to socio-demographic data from Roble Norte is nonexistent, thus this zone cannot be properly characterized. Also, the available information cannot be used to propose solutions in this research line due to its antiquity.
- The data collected from different government institutions differ among them, even when

they have been gathered in the same period of time. Therefore, the information is not reliable and sometimes is contradictory.

- The information obtained from the fires that occurred in informal settlements throughout the year is the total number for the country. This data is not divided by provinces or settlements; thus, it is difficult to know which is the zone that faces the most fire issues.

Limitations in La Carpio

- There is an absence of legal division in the informal settlement. The institutions have their own sector divisions and may or may not be similar, hence when requesting information of Roble Norte, the data collected for the same sector could or could not match between different institutions.

- Good communication with the community association was not established due to the absence of response of their communication channels. As well, the community meetings are held at night, introducing a high risk to the author if they were attended. This impeded to know and include in the document the perspective of the community about the fire safety issue.

1.5 Definitions

To understand in a completely way the subject will be developed herein, some concepts must be defined, since, many of them are confounded or misunderstood most of the time. Following will be described some essential concepts with information retrieved from reliable sources as INEC, MIVAH, TECHO, among others. One of the goals this research wants to achieve is to establish a vocabulary that can be used in a general way when referring to the informal settlements' matters.

Precarious
According to the Department of Housing and Human Settlement of the MIVAH: The precarious condition refers to the tenure of a terrain where is located a dwelling, when it has not been formalized with the Municipality or the Property Register, despite the years they have occupied the land; the above can imply that the built dwelling in the mentioned terrain, could be in a good, regular or a bad condition (MIVAH, 2013).

Shanty house
Enclosure built provisionally with waste materials, usually in disrepair. This kind of dwelling is built to solve an immediate necessity of shelter and commonly are improvised (INEC, 2013).

Informal settlements
Are settlements that were formed as a product of the calls "tomas de tierra" (taken terrains) organized or not, which, ones more than others, with the past of the time, enhance certain conditions, as the infrastructure of the dwellings and the access to public services. They may or may not have shanty houses (INEC, 2013).

According to United Nations (UN, 2015), the informal settlements are residential areas in which:

1. The inhabitants do not have tenure rights over the lands or dwellings they live in, so they reside under modalities that go from illegal occupancy to informal leasing.
2. The neighborhoods usually have a lack of basic services and urban infrastructure.
3. The dwellings may not accomplish with the building and planning regulations and these houses usually be geographically and environmentally located in hazardous areas.

For this project, the definition used for informal settlements will be the one stated by the United Nations.

Slum
A heavily populated urban area characterized by substandard housing and squalor (UN, 2003, p.8).

Dwelling
A physical structure used by human beings to sleep, prepare and consume food; as well as to protect themselves from the inclemency of the weather (INEC, 2013).

Overcrowding
A dwelling is considered overcrowded when it has more than 3 people per room (INEC, 2013).

House tenancy
It refers to the condition of home ownership by the people who inhabit it, thus the house can be own fully paid, own paying in terms, rented house, borrowed house, or in precarious condition (INEC, 2013).

Habitual resident
A person who at the moment of the census had six months or more inhabiting the dwelling or having less time but does not lived in another place and had intentions of stay in that place (INEC, 2013).

In this research, the use of words like slum and shanty houses will be avoided since it could be interpreted as despising to the population inhabiting in these settlements. Another reason is regarding ethics since there is not morally correct to use vocabulary that can affect people psychologically.

2. Background

This section will begin developing the specific objective one mentioned above. As this project is a newfangled subject, past theories applicable to this issue were not found. Thereby, this project along the document will follow an exploratory line, with the main intention of showing the reader the existing information obtained by the author and document it in this research.

This section describes the state of the art of informal settlements issues around the world. Then it describes the situation of informal settlements in Costa Rica, and some initiatives developed by several institutions in order to enhance these issues in the country. Finally, it contextualizes the fire issues within Costa Rican informal settlements. The information found by the author concerning the overview and fire records in Costa Rican informal settlements will be displayed here.

2.1 Informal settlements in the world

The world is becoming increasingly urbanized. According to the United Nations (n.d.), half of the population –3.5 billion people– lives in cities today and 5 billion people are projected to live in cities by 2030. It is expected that 95 percent of urban expansion in the next decades will take place in the developing world (UN, n.d.). Slums and informal settlements located in developing countries currently accommodate close to 1 billion people and this number keeps rising (UN-Habitat, 2019). Therefore, the number of people living in informal settlements will increase at the same rate as the population does.

The appearance of informal settlements and slums are caused by a series of interrelated factors according to the United Nations (2015). The population growth and rural-urban migration are one of the factors that leads to the upgrowth of informal settlements. The lack of affordable housing for the poor population living in cities also triggers the creation of dwellings in sub-standard and illegal conditions. Other factors like deficient governance, economic vulnerability, and poorly paid workforce, boost the people with the least monetary resources to settle in these informal settlements, being the only apparent chance to establish a home. The discrimination, marginalization and displacements due to conflicts is another factor that bind the people to move into other places, mostly into informal settlements, due to the easiness to establish new houses in short periods. The consequences of natural disasters and climate change can also boost the population to move into informal settlements. It has been estimated that one in four urban residents in the world live in slum-like conditions (UN, n.d). This global population growth tendency has rapidly increased and the issues related to the lack of housing, decent living conditions and the emergence of informal settlements or slums are getting worse through the years.

Due to several problems in distinct fields that are challenging all the countries around the world,

the 2030 Agenda for Sustainable Development was adopted by all United Nations Member States in 2015. It provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. It gathers seventeen Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership (UN-SDGs, 2015). The most relevant goal to this research is the eleventh goal, which is related to sustainable cities and communities and has the intention of making cities and human settlements inclusive, safe, resilient and sustainable (UN-SDGs, 2018).

Every year, information about the progress of the eleventh goal is published. The most recent report in 2018 outlined that, for 2014, the number of people living in slums increased to 883 million (UN- SDGs, 2018). This means that around thirty percent of the total urban population worldwide lives in slums (The World Bank, n.d.). Of these 883 million, 21.26 percent corresponds to the population of Latin America and the Caribbean, meaning 103 million people are living in informal conditions in those areas (UN, 2014). This number illustrates that 24 percent of the total population of this region lives in slums (UN, 2015).

At the same time, as the population grows, so do the housing needs, driving the emergence of informal settlements and/or the increase of the amount of people living in the existing ones. There has been a gradual shift in the world from informal settlement eradication to informal settlement upgrading in recent years (Cirolia, et al., 2016). The political efforts sometimes are not enough to solve these issues. The evolution or emerging of this kind of settlements is faster than the solution, therefore the upgrading of the settlements has been deemed a better solution for the governments than their eradication. Providing basic services and improving quality of life conditions is easier than displacing a large number of inhabitants to other zones and giving them houses.

Another issue is that the informal settlements are usually in hazardous areas under risky conditions. Depending on the season, they could be affected by different threats. For example, in the rainy season, they often suffer floods due to the absence of sewage and the soil saturation provokes landslides. Illegal electrical connections can also be affected by rain which can trigger short circuits and fires. In summer, the dried grass near the dwellings is in constant danger of catching fire, and, in some cases, neighbors burn the dry grass offcuts provoking fires that get out of control. The people living in slums and informal settlements are very vulnerable and one of the main risks they are exposed to is fires. They live in constant danger of losing everything they have, which can be distressing for the inhabitants of these zones as they are extremely poor.

Besides the hazardous conditions and the houses in disrepair, the population living in informal settlements have a high likelihood of suffering fires that could lead to injuries or deaths. It is estimated that, worldwide, 180 000 deaths every year are caused by burns and the vast majority occur in low- and middle-income countries (World Health Organization [WHO], 2018). In 2016, around 153 000 people died by fire, heat or hot substances, of which an approximate 7000 of these deaths occurred in the North, Central and South Americas (WHO, 2018).

Currently, several people are becoming aware of this problem. Enterprises and academia are beginning to develop projects or research related to this issue, trying to enhance the living conditions of the people inhabiting these zones. For instance, ARUP, a multinational enterprise, has started developing research related to fire security in informal settlements because they noticed the awful effects the communities suffer after a fire. Their investigations gave as a result a framework for fire safety in informal settlements. This document has been developed to facilitate collaboration and alignment of global efforts to create safer and more resilient informal settlement communities. It intends to assess fire risk in informal settlements and be a point of reference for stakeholders seeking to better understand fire safety (ARUP, 2018). In addition, the framework looks to help particular informal settlements by supporting them with a holistic consideration of fire risk and potential risk reduction options. It should be noted that sometimes countries' differences or cultural beliefs may present challenges when approaching fire safety and evacuation strategies (ARUP, 2018), which can be observed in one of the study cases they developed.

Another research project is IRIS-Fire, developed between engineers and social scientists. This project looks to improve the resilience of informal settlements to fire. This project, conducted by the University of Edinburgh, UK and Stellenbosch University, South Africa, is focused on informal settlements located in the Western Cape of South Africa and beyond (IRIS-Fire, n.d.). Investigators within the IRIS-Fire project also aim to develop innovative methods of assessing and modeling fire risks with the goal of increasing informal settlement fire resilience. Gibson et al. (2018) published a paper which outlines a new approach to mapping historic and ongoing fires in informal settlements using remote sensing and satellite imagery. Though the awareness about this problem is increasing and some efforts to enhance the matter in question are being done, it is noticeable that much work still needs to be done.

2.2 Informal settlements in Costa Rica

The housing issues in Costa Rica has been one of the most serious social problems since the beginning of the twentieth century. There are records since 1904 about government actions focused on solving housing problems that affected the country. With the first executive decree called *"Reglamento sobre chinchorros y casas de vecindad"* (Regulations on hovels and neighborhood houses), the government was looking to establish the minimum conditions of health, services and hygiene of the dwellings (Mora, 2014).

Over the years, the policy and laws evolved as the situation did. In 1949, it was established in the Costa Rican Political Constitution that the State had the obligation of providing decent housing to the population with limited economic resources (Mora, 2014). In 1978, the deficit and the poor conditions of housing affected sixty-five percent of the country population. In the next years, the dwelling situation forced the society to manifest through organized demands which originated social and political pressures, favoring the creation of informal settlements (Mora,

2014). Combined with those manifestations, other phenomena in the eighties, like migration from the countryside to the city of interurban and internationally, and the industrialization and the depletion of low-cost lands, made it more difficult for the development of housing solutions for the poor population by the State. This situation prompted the organization of groups who fought to satisfy the needs for housing and basic services (Ministerio de Vivienda y Asentamientos Humanos [MIVAH], 2014).

Due to the insufficient response of the State, the population form groups and invade public and private lands to obtain a solution of provisional housing. This measure puts pressure on the government to identify a possible final solution, however, this situation promotes the creation of informal settlements (MIVAH, 2014). Although some say the beginning of informal settlements was in the seventies, it was in the eighties when they began to proliferate as a solution for the society due to the housing deficit in the country (Mora, 2014).

Performing a review of the data collected in the report related to the upgraded database of informal settlements for the period of 2011 – 2012 by the Ministerio de Vivienda y Asentamientos Humanos (MIVAH, Ministry of Housing and Human Settlements), it was found that Costa Rica had 384 settlements in condition of informality during those years. **Table 1** shows a summary of these settlements distributed per province and location inside or outside the Gran Área Metropolitana (GAM, Great Metropolitan Area).

Table 1. Informal settlements per province and location inside or outside GAM, years 2011-2012.

Province	Outside GAM	Inside GAM	Total by Province
Alajuela	25	21	46
Cartago	7	35	42
Guanacaste	58	0	58
Heredia	2	13	15
Limón	33	0	33
Puntarenas	61	0	61
San José	7	112	129
Total	**193**	**191**	**384**

Source: (MIVAH, 2013, p.12), 2015-2019

Furthermore, the MIVAH determined the growth of the number of informal settlements per set span of years, showing that the largest proliferation of informal settlements occurred during the seventies and eighties. **Table 2** shows a summary of the data collected.

Table 2. Informal settlements per province and location inside or outside GAM during the years 2011- 2012.

Foundation Year	Quantity of IS	Percentage of the total
Before 1969	32	8.33
From 1970 to 1989	160	41.67
From 1990 to 2000	131	34.11
From 2001 to 2012	38	9.90
Not specified	23	5.99
Total	**384**	**100**

Source: MIVAH, 2013, p.12
Note: Understood IS as Informal Settlements.

Many organizations have been trying to determine the number of informal settlements which are established in Costa Rica, but, most of the time, the numbers between the different investigations do not match. Due to this fact, some organizations are working together to determine the exact number of existent informal settlements in the national territory. An investigation developed by Mora in 2014 regarding the number of informal settlements compares the information gathered by MIVAH and the data from censuses and national surveys obtained by Instituto Nacional de Estadísticas y Censos (INEC, National Institute of Statistics and Censuses) (Mora, 2014). This comparison showed big differences between the data, due mainly to the distinct methodologies employed in the data collection. In this investigation, an alternative methodology was employed which used the database of informal settlements from MIVAH, the digital cartography from INEC and the database from the X National Population Census and VI Housing (Censo 2011) in order to specifically get information for each one of the informal settlements identified in the country. This research gave as a result a total of 418 informal settlements (Mora, 2014).

Related to the investigation developed by Mora, in 2012, TECHO (headquarters Costa Rica) began with the planning of the National Cadastre of Settlements in Poverty Condition. TECHO is an organization settled in nineteen Latin American countries which seeks to overcome the poverty situation of millions of people who live in settlements through joint actions of their inhabitants and young volunteers (TECHO, n.d.). Their project aimed to identify and describe the reality of the settlements in poverty condition of the country (Mora, 2014). Starting from this initiative, an alliance was established between TECHO and INEC with the objective of joining efforts to support the elaboration of the Cadastre and, at the same time, validate the information in situ of the informal settlements identified with the described methodology (Mora, 2014). This exercise makes possible the junction of three databases, INEC, MIVAH and TECHO, to create a more exact record of the informal settlements of the country (Mora, 2014).

In 2014, TECHO published the Catastro Nacional de Asentamientos en Condición de Pobreza (CNACP, Report of the National Cadastre of Settlements in Poverty Condition). The investigation was undertaken in different communities. A set of participants from local communities

were interviewed through a survey which allowed for the collection of information, covering the history and founding of the settlement to the current strengths and problems (TECHO, 2014). The main objective was to identify the Costa Rican settlements in poverty condition for the second half of 2013, related to the delimited geographic location and features (TECHO, 2014). The report performed by TECHO showed the existence of 394 informal settlements distributed as shown in **Table 3**.

Table 3. Quantity of informal settlements according to TECHO report.

Province	Quantity of IS	Percentage of the total
San José	104	26.4
Alajuela	58	14.7
Cartago	30	7.6
Heredia	29	7.4
Guanacaste	38	9.6
Puntarenas	45	11.4
Limón	90	22.8
Total	**394**	**100**

Source: TECHO, 2014, p.13
Note: understood IS as Informal Settlements.

Finally, the most recent effort to understand the situation of informal settlements is still in progress by MIVAH. Its first product is an inventory and a georeferenced spatial location of the informal settlements within the country. This database identified a total of 679 informal settlements. This larger amount does not necessarily mean the emergence of new settlements, but in some cases indicates a difference in classification of what has been happening on the ground (Fundación Promotora de Vivienda [FUPROVI], 2019). In this new inventory, the number of informal settlements is larger because some bigger settlements now have segregated in smaller ones.

In this new effort, MIVAH offers valuable, accurate and upgraded cartography; nevertheless, it has a deficiency regarding the content of the settlements. The exact location of the settlements is known, but no detailed information exists (FUPROVI, 2019). This cartographic update makes a correlation of the MIVAH database and other institutions, whereby a cartography updated for the year 2019 was obtained per canton, which contains information about the estimated population for each informal settlement. The fieldwork to validate the obtained cartography remains to be performed, same as the information of the other variables of these settlements (FUPROVI, 2019). The informal settlements are sometimes difficult to measure as most of them are established under secrecy, and they grow and change at a great speed. This results in the data being quickly outdated, which means that it is complicated to obtain accurate information about the real number and status of informal settlements in Costa Rica.

2.3 Past projects upon Costa Rican informal settlements.

In addition to all the efforts done for gathering and updating information concerning informal settlements, several institutions have been trying to solve this living informality condition through projects or investigation. Related to research, the Programa de Investigación en Desarrollo Urbano Sostenible (ProDUS, Research Program in Sustainable Urban Development) an entity belonging to the Civil Engineering School of the Universidad de Costa Rica (UCR, Costa Rica University), developed two reports for the Estado de la Nación (EN, State of the Nation). In 2004 it did the report of social segregation and in 2005 the analysis on the spatial location of the precarious in the GAM. The latter report pretended to establish patterns of appearance-disappearance of precarious in the GAM and determine the socioeconomic patterns of these settlements against the surrounding urban realities (ProDUS, 2005).

On the projects side, the Fundación Costa Rica–Canadá (Costa Rica-Canada Foundation) is an entity which helps to solve housing issues, authorized by the Sistema Financiero Nacional de Vivienda (SFNV, National Housing Financial System) an organization which raises funds to solve housing problems. The foundation manages funds or the Banco Hipotecario de la Vivienda (BANHVI, Mortgage Housing Bank), and provide credits from own resources to solve housing issues. As of 2006 this foundation is an executing unit of the eradication of precarious program of the Costa Rica Government. This Foundation intervenes mainly in informal settlements located in State properties, also they give to the families of this kind of settlements new and enhanced infrastructure, new or repaired houses and land titles.

In 2007 several institutions gathered and performed three workshops on FUPROVI facilities. These workshops were performed by the Commission of Experimental Norms in the Process of Reforms to the Urban Development Plan (PDU) of the Municipalidad de San José (MSJ, San José Municipality). The objective was to analyze the experiences different institutions had when applying proposals in informal settlements, in order to draw special norms or guidelines that can help to intervene with the urbanistic attention of these settlements. In these workshops participated several institutions like the MIVAH, INVU, Fundación Costa Rica-Canadá, FUPROVI, Ministerio de Salud (Health Ministry), CNE, AyA, ICE, Fire Department of Costa Rica, SETENA, UCR, and MSJ. These meetings allowed to obtain several conclusions in different topics as general rules or design criteria, specific rules or design criteria, minimum dimensions, design criteria in emergency situations, health, citizen security, and formalities.

In 2008 the MIVAH creates the Programa de Erradicación de Asentamientos en Condición de Precario y Tugurio (PEPT, Settlement Eradication Program in Precarious and Slum Condition) in 2008, which responds the request done for the Contraloría General de la República (General Comptroller of the Republic) in the framework of established dispositions through the inform No. DFOE-SOC-51-2008, where is settle the necessity of a general policy plan regarding to attention of informal settlements. Besides asking for the plan, it was also requested to the MIVAH

the actualization of the SINVI system and to perform a strategy for tracking and assessing the projects related to the PEPT program. (MIVAH, n.d.)

The plan consists of three interrelated stages, the first one is the establishment of the SINVI tool to perform the pre-selection of the settlements, according to the necessities and attention possibilities. In the second stage, the strategies and guidelines to facilitate the settlements' attention are made. In this stage, the State must be performed a feasibility attention process, based on the general diagnostic of the demand done. The last stage includes in the plan the strategy for tracking and assessing the projects linked to the attention of the informal settlement in precarious and slum conditions, with a multi-criterial model tool, which will allow to make recommendations and guidelines for the elaboration of the attention plan that must be done and implemented by the BANHVI, through the SFNV. (MIVAH, n.d.)

2.4 Fire record in Costa Rica

In Costa Rica, the institution in charge of the fire protection and other hazards is called Benemérito Cuerpo de Bomberos de Costa Rica (Fire Department of Costa Rica). Within this institution is the Unidad de Ingeniería del Cuerpo de Bomberos (Fire Department of Costa Rica Engineering Unit), department in charge of the investigations related to fires, dangerous materials, and others. One of the duties of the Engineering Unit is to generate a report at the end of the year that shows the record of the fires that occur in the country. This report collects the details of the fires, and then classify them by category. **Table 4** shows the total fire emergencies that occurred in the last five years, and which of these were structural fires. Within these structural fires, **Table 4** also indicates how many were investigated by the Engineering Unit.

Table 4. Fire emergencies attended annually.

Year	Total emergencies	Structural fires	Analyzed by the Engineering Unit
2015	16,600	978	170
2016	18,065	1,063	179
2017	15,308	1,062	157
2018	16,720	1,126	134
2019	19,302	1,061	128

Source: Fire Department of Costa Rica Engineering Unit, 2015-2019

As the table illustrates, the Engineering Unit does not analyze all the structural fires registered. This was inquired into, and a member of this department explained that to investigate a structural fire, the accident must meet certain requirements like: be accidents that involve deceased people; fires in hospital, penitentiary, public meeting, state buildings or educative centers; fires in areas

that covers more than hundred square meters; fires where the control time surpass thirty minutes after the dispatch of units; and fires in structures who have an insurance policy. If the fire does not meet one of these requirements, an investigation is not obligatory. In the Engineering Unit reports, data related to the number of deaths and number of informal settlement fires as part of the total structural fires per year can be found. This has been summarized in **Table 5**.

Table 5. Fires in informal settlements and deaths per year.

Year	Structural fires	Informal Settlement fires	Deaths
2015	978	37	12
2016	1063	42	18
2017	1062	59	13
2018	1126	50	30
2019	1061	41	15

Source: Fire Department of Costa Rica Engineering Unit, 2015-2019

It can be observed that the number of fires in informal settlements has a fluctuant behavior, as well as the number of deaths. However, it should be noted that these fires have a high probability of having as a consequence loss of life and property, the latter in high scale.

As mentioned previously, the Engineering Unit does not investigate all the fires that occur. When fires occur in informal settlements, the Engineering Unit does not always gather detailed information. There is only an estimate of the fires attended by the Fire Department of Costa Rica, and this data is given for the whole country, whereby, lacking proper research, does not allow the real magnitude of the issue to be known. Moreover, the Engineering Unit has identified that, in recent years, the main two fire causes are electrical systems failure and electronic device failures. Other causes that generally start fires but with less concurrence are shown in **Figure 2**. This figure illustrates the classification of the 128 fire events that have occurred and were investigated in 2019 by the Fire Department Engineering Unit.

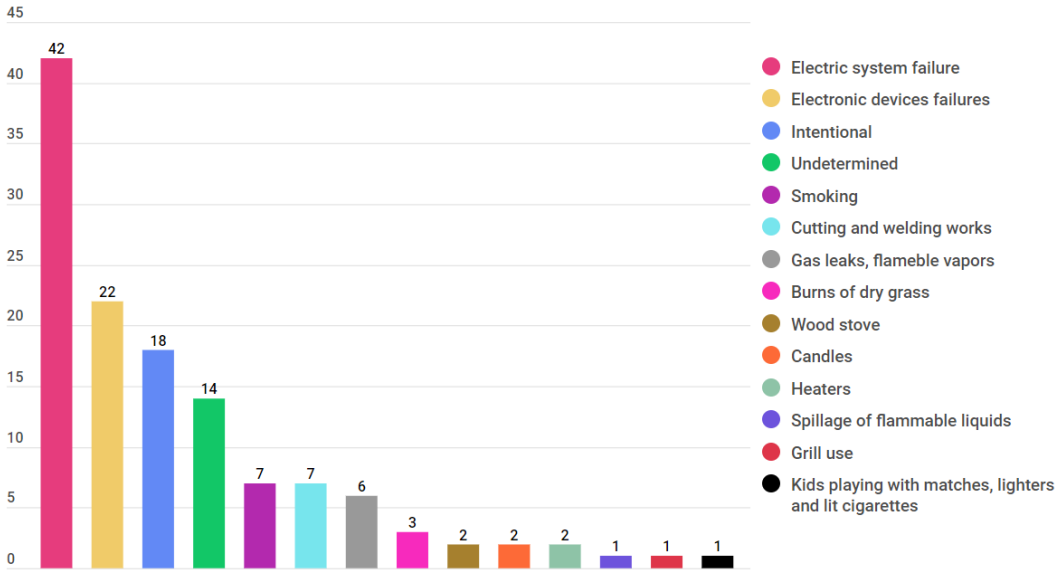


Figure 2. Fire causes in 2019.
Source: Fire Department of Costa Rica Engineering Unit, 2019.

Though there are an overview of the fire causes in structural fires, these are mostly for structures in good condition and location. As observed in **Table 5**, the number of fires in informal settlements is just a little percentage of all the structural fires occurred per year in Costa Rica (3,86% in 2019). Most of the time, these fires are not investigated, so there is an assumption of the fire causes but there are no statistics or real data that allows determining the main fire causes in these particular settlements. What is truly known is the high likelihood of the dwellings in these settlements of suffering fires, most of the time due to lack of house planning, using combustible materials for housing construction, the deplorable status of the electric systems (usually electricity stolen from the main lines), among other reasons explained further. Finally, some fires occurred in informal settlements are described below. These ones are the biggest and most significant of the past years.

In November 26th, 2016, the informal settlement “Los trillizos” located in León XII district, Tibás canton, experienced a fire which took the lives of 6 people and affected 100 houses, in an area of 3000 m2, leaving more than 180 people without housing (El Guardian, 2016). The cause of this fire was determined as provoked since after a couple discussion, the male decided to start a fire in his partner house and then the fire spread through the settlement. **Figure 3** shows the affected zone.

Figure 3. Los Trillizos fire footprint.
Source: El Guardián, 2016.

On April 13th , 2019, Roble Norte, a sector of the informal settlement "La Carpio", located in La Uruca district, inside San José canton, suffered a fire that affected two structures in 550 m2, leaving 7 victims. This fire is a key event for this research since it occurred in the selected study zone and also because it caused 46.66% of the deaths reported by the Engineering Unit in 2019. **Figure 4** was taken a month after the fire and it shows the remains of the house.

Figure 4. Dwelling burned in La Carpio fire.
Source: Author's photo. May 7th, 2019)

Another event which happened recently was El Pochote fire. This fire took place on September

16th, 2019, in Barrio Cuba, a neighborhood part of Hospital district, within San José canton. The fire burned 40 houses located in 2400 m2, leaving around 216 people homeless according to the Engineering Unit fire report (2019). The cause of the fire was a short-circuit. **Figure 5** shows the damage caused by the fire.

Figure 5. El Pochote fire footprint.
Source: Jason Fernández, San José Municipality

More recently on January 15th, 2020, the "Los Sauces" informal settlement located in Guararí neighborhood, which belongs to the San Francisco district, inside Heredia canton, suffered a fire that razed 189 houses located in 8400 m2, affecting around 532 people (La Nación, 2020). It has been categorized as the biggest fire attended in informal settlements of Costa Rica. **Figure 6** shows the damaged area left by the fire.

Figure 6. Los Sauces fire footprint.
Source: Yaslin, C.

The Fire Department of Costa Rica are conscious of the high risk to the people inhabiting these

dwellings. In fact, they analyze the conditions of 462 informal settlements and created a map that will allow them to make decisions when attending future fire emergencies (La Nación, 2019). Héctor Chaves, director of the Fire Department of Costa Rica, commented for La Nación newspaper that from the 462 informal settlements studied, 10 were identified as the ones with the highest fire risk. These are distributed throughout the country and are called: "Las tenis" from León XIII (Tibás), "Finca San Juan" and "Rincón Grande" (Pavas), "Los Cuadros" and "Los Colochos" (Guadalupe), "Cuenca Guararí" (Heredia), "La Carpio" (Uruca), "Los Sitios" (Moravia), "El Erizo" (Alajuela), "María Auxiliadora" (Cartago) and "Barrio Chorotega" (Santa Cruz). Chaves also mentioned that having an emergency plan or emergency meeting points established could help the Fire Department during an emergency, which will let the emergency units know if someone is missing and thus the people searching will be most effective. Finally, La Nación newspaper mentioned in the article that the MIVAH prioritized 45 districts aiming to reduce the list of informal settlements existing. The project intends to enhance holistic way affairs like health, education, work, and housing.

3. Methodology

Due to the novelty of the subject, the development of this project followed an exploratory investigation procedure. To obtain the information needed, both research methods, the qualitative and quantitative systems, were employed, with the intention to gather all the general features that describe the informal settlement and the matter in question. The project embraces several tools to collect information. In the qualitative strand, interviews and field visits were carried out. Concerning the quantitative branch, a series of statistical data collection was performed.

Related to the interviews carried out, these were composed of open-ended questions, leading this to grasp the opinion of the people consulted. A total of five interviews were performed, four in Fire Brigade Stations applied to 20 people, and one interview to a member of MIVAH. Also, one meeting with a member of the MSJ was performed, in here some overview information of La Carpio was commented, and some material was collected. All these interviews and meetings were performed along the first semester of 2019.

This chapter will describe the methodology employed to collect the information shown herein and the results obtained in order to describe in a qualitative and quantitative way the study zone. It must be noted that the photographic record was mainly performed for the Roble Norte sector. All the results will be displayed ordered according to the determined zone, being La Carpio or Roble Norte separately. In order to comply with the provisions of specific objective two, the tools and processes followed for information gathering will be described below.

3.1 Firefighter Interviews

Since this is a project which involves fires, it is necessary to know the perception of the main actors on these events. This research includes the viewpoint of the firefighters relating to the fires in informal settlements, as well as their opinions and description of the events from their experience. The main intention is to know how they observe the issue and what they think about it. They can provide valuable feedback because they are in constant relation to the problem. During the interviews, some of them proposed solutions that could be functional, which will be discussed further.

Before carrying out these interviews, permission was requested from each station. To obtain the permission, a meeting was carried out with the Engineering Unit, where they gave to the author the contacts of the people in charge of the stations selected. The author then sent, via e-mail, a letter asking for permission to conduct the interviews. Permissions were granted, and the interview dates were scheduled.

To collect the firefighters' opinions, two interviews were performed in two different stations. The

interview process started in the Barrio México station and ended in the Pavas station. These two stations are located in San José and were selected due to the proximity to the settlement in study. In addition, they were chosen due to the number of fires and emergencies in informal settlements they attend, as the Pavas station is the one who handles the most fire cases in these kinds of settlements in Costa Rica. The interviews were undertaken during two different workdays, allowing for the collection of information from a greater number of firefighters due to the shift work. These interviews were implemented through face-to-face meetings. In the Barrio México station, the interviews were performed individually, meanwhile, in Pavas station the interviews were done in groups.

Before the interviews were conducted, a survey was constructed with ten open-ended questions in order to grasp the firefighters' opinions about their experience regarding fires in informal settlements. The questions were planned according to several topics related to their experience attending fires in informal settlements. The interviews collected details of the challenges the firefighters face in this kind of fires, as well as additional details like causes of the fires, fire detection tools. **Table 6** below shows the different themes selected to formulate the questions of the survey, and why it is relevant to know their answers.

Table 6. Themes selected to write the questions and their relevance.

Theme	Relevance
Causes of the fires	The main issues that trigger fires in informal settlements and that can have unique features for these zones.
Fire detection and warning tools	Which alarm systems are used for fire warning situations and their effectiveness.
Response time	Which factors intervene in the response of a fire event.
Fire extinguish time and differentiation between settlements	Which factors affect the fire extinction time and what differences could be found between attending fires in these zones versus suburbs.
Strategies and equipment use to fight fires	Which tools, techniques or products are used in fire extinction due to possible differences in construction materials.
Advice for communities	How the Fire Department interfere with prevention issues and what type of advice or preventive measures they give.
Experience in past events	Feedback of past experiences could help to better address the problem.

The intention of collecting this information, beyond having a wider vision of the problem, was

to comprehend how to better address the research, and to document the firefighters' opinions. Since there is no previous information nor understanding of the magnitude of the issue, hence it is difficult to orienting the investigation and determining where to start. The questions performed to the fire stations can be found in appendix 1.

3.2 Ministry of Housing and Human Settlements (MIVAH) Interview

As housing is the main factor of the investigation, it is essential to have the viewpoint of a representative of the MIVAH. For this research, the opinion of Mauricio Mora, the vice minister advisor and coordinator of the inter-institutional table of La Carpio, was obtained. To acquire permission, a request via e-mail was done to the vice minister's office, and then a meeting was scheduled for August 13th, 2019. The interview was carried out face-to-face in the MIVAH main office located in San Pedro, San José. The interview was composed of eleven open-ended questions regarding several topics, including overall information concerning informal settlements and La Carpio specifically. These topics will be summarized in **Table 7** below.

Table 7. Themes and details considered to write the questions.

Theme	Detail
Actions done	What actions is the MIVAH doing regarding to informal settlements.
Projects and stakeholders	Are they developing projects in La Carpio. If there, what is the current situation of the projects and which stakeholders are involved.
Risk hierarchy	Which hazard they consider is predominant in the risk hierarchy in this settlement.
MIVAH in fires	How they intervene in fire events, and how do they can help regarding fire safety or which entity considers that must be more involved in the subject.
MIVAH objectives	Which is the main objective in relation to informal settlements, do they see a feasible solution for the issue.
Update database	How can be obtained a database with sociodemographic and physical features of the informal settlements that can keep up to date.

Knowing the opinion of the MIVAH will allow the author to collect background information, to analyze and comprehend their perspective of the matter, to know what projects they are developing, and also understand what was their main intention and why they decided to encompass the issue with this solution. All the information obtained through this interview will help the author to have an overview of the real situation faced in these community, and to guide the research in the best direction. It is difficult to handle the investigation with the existing gap of knowledge in fire safety in informal settlements subject, therefore the MIVAH opinion will help to know the past issues detected and how to embrace them to find a holistic solution. The questions performed in the MIVAH interview can be found in appendix 2.

3.3 Field visits

Before approaching the topic, it was necessary to know the place, the people and the conditions under which they live. The first contact with the community was through a business tour between MIVAH and the Consejo de Desarrollo Comunal de La Carpio (CODECA, La Carpio Community Development Council). In this tour, the community members of CODECA guided a walk through the main streets of La Carpio, while discussing some of the problems they face in the settlement. In addition, the map used by the inhabitants of La Carpio which outlines the community sectors was given on the tour.

The second visit required more planning since the author was going alone to collect visual information. To preserve the safety of the author, an accompanied visit was recommended by several professors, thus, it was decided to draw upon the correspondent police department. To coordinate the visit, the first step was determining which police delegation is in charge of setting the police officers' duties in La Carpio police station. It was found out that Mata Redonda police delegation is the one in charge of this function. Then a letter to Luis Alonso Leiva Hernández, superintendent of the Mata Redonda police delegation, was sent asking for a meeting. In the reunion, the author explained the thesis objectives and the importance to carry out a field visit to gather some qualitative features needed. After the explanation, the police accompaniment requested was approved. After the approval, the superintendent communicated to the chief of La Carpio police station about the visit and he appointed a couple of police officers as escorts.

The visit was performed on May 7th, 2019, during which a series of photos and videos of the Roble Norte sector were collected. When the visit was done the author realized that the zone Las Gradas, inside Roble Norte sector highly depicted the issue discussed herein. To scale and have an approximation of the dimensions of the streets, a wood meter was put in the middle of the streets and then the pictures were taken, allowing to have a presumption of the real measures.

3.4 Other data collected

Several institutions like the MIVAH, INEC, MSJ, Sistema integral de formación artística para inclusión social (Sifais, Integrated system for artistic training and social inclusion), Compañía Nacional de Fuerza y Luz (CNFL, National Force and Light Company), Acueductos y Alcantarillados (AyA, Aqueducts and Sewers), Caja Costarricense del Seguro Social (CCSS, Costa Rican Social Security) through La Carpio health center, Fire Department of Costa Rica, and Instituto Mixto de Ayuda Social (IMAS, Institute of Social Assistance) were contacted in order to gather information regarding to physical and statistical features of the study zones and the issues that affects them. Maps, statistics, documents, GIS vectors, and others were collected. Regarding GIS vectors the Atlas of Costa Rica performed by the Instituto Tecnológico de Costa Rica (ITCR, Costa Rica Institute of Technology) will be used, since it has general data of all the country that could help to characterize the study zones. This data in the vast majority is out of date and incomplete, however, it can be used to understand previous analysis performed by different institutions, and to comprehend some of the problems detected by them.

The information request was sent by e-mail since in most of the cases there was not necessary to carry out a meeting or interview to grasp this information. The only meeting carried out was with Oscar Núñez a member of the MSJ, in this meeting a web page called DesInventar was recommended to obtain data related to emergencies. This online software registers all the disasters that have happened in the country an generates an inventory that could help to determine the risk hierarchy in the study zone.

Another web page used was the Social Maps available on the INEC website. This website shows work regions of several institutions, different boundaries like the province, canton, district, and the informal settlements detected by the INEC. Although the webpage was available and functional, the author rather to work with the vector of this map. This file was shared by one member or the Information and Statistical Disclosure Services Area of the INEC, therefore the author used ArcGIS and QGIS software to analyze the information and make images that allowed to depict the area.

To obtain some specific data from the INEC, it was necessary to do an arrangement between the INEC and the author, first observing how much information can be appealed for and then how much it will cost for that information. This is because some of the information collected by them is not public, as one of their duties is to keep safe and not expose the people surveyed. Depending on the extension of the study zone, there are several variables that can be asked, in this case for the Roble Norte sector it was possible only to ask for five variables, which are: predominant materials in exterior walls, predominant materials on the roof, main fuels used to cook, habitual residents in a dwelling, and total of homes according to the number of persons in a house. The last one will not be commented since it is focus on the number of homes not in the number of inhabitants of the house.

This research will show all the information gathered by the author and will discuss the reliability

of the data collected. In further sections, this information will be compared between institutions, with the main intention of showing to the reader how difficult it could be to work to this issue with information that does not match between them, even when developed on similar dates.

4. Results

This section contains all the information gathered from several institutions mentioned previously. It describes the information according to the study zones, La Carpio and the Roble Norte sector. A series of comparisons between collected information will be done and discussed. It should be taken into account that some images, though collected by official institutions, are not the definitive ones due to the informal condition of the settlement in the study. Moreover, it should be noted that at the beginning of the research, the intention was to work just with the Roble Norte sector but information of both La Carpio and Roble Norte sector will be displayed, since there is a huge lack of information which impedes the analysis or conclusions made regarding the subject just using the sector data.

This section shows the information taken from La Carpio and Roble Norte, from several entities consulted. **Table 8** summarizes the information gathered from these entities, and it divides it depending on the location, being information related to La Carpio or Roble Norte. This information gathering was carried out to accomplish with the settled in the specific objective two.

Table 8. Entities consulted for information gathering.

Entity	La Carpio	Roble Norte
Fire Department of Costa Rica	x	
Police (field visits)		x
MIVAH	x	x
INEC	x	x
La Carpio health center		x
IMAS		x
MSJ	x	
INCAE	x	
CNFL	x	
ATLAS	x	

4.1 La Carpio

This subsection will describe the statements taken from the firefighters and the MIVAH member, also it will comment on the situation of the risk hierarchy of La Carpio, and finally, it will display other data collected from several institutions.

4.1.1 Statements from firefighters' interviews

The interviews performed with the firefighters allowed information related to the extinguishing process and human behavior in fires in informal settlements to be obtained. As shown in the previous section, the questions were formulated under specific themes. In this section, the information gathered will be discussed according to the subject they were classified.

Causes of the fires
Some of the causes of fire ignitions in these kinds of settlements have unique characteristics. Usually, the people living there have surreptitious ways of life, which leads to uncommon causes to ignite a fire compared with houses located in formal zones. Many of the causes mentioned by the firefighters were related to bad electrical connections, short circuits, cooking with open flame (in irregular ground causing stove fall), bad manipulation of gas cylinders, provoked fire (vengeance), dwellers performing welding tasks near mattresses, dry grass or wire burns, lit cigarette butts, candles or wood-burning cooker turned on without surveillance, neglected children playing with matches, candles or left alone in their houses, among others.

Nevertheless, the main causes of the fires which occurred per year are strongly bound with the season. For example, in the dry season, the most number of fires are related to non-controlled grass burns which affect the surrounding structures, meanwhile, in the rainy season, the most common cause of the fires is short circuits due to the high humidity of the environment, which can cause moisture in the electrical connections.

Fire detection and warning tools
Currently, the only emergency alert system in use is calling 9-1-1, though the dispatch of the fire units is managed by the Office of Operative Communications (OCO), a department belonging to the Fire Department of Costa Rica. The 9-1-1 receives the call and verifies it; at the same time, the information is being transmitted to the OCO, which communicates to the corresponding station via radio and performs the dispatch of the units. For informal settlements, the only difference in the emergency alert process is the verification of the call. When the call enters 9-1-1, they immediately communicate to the OCO and then they make the dispatch. But the verification process is carried out while the units are on their way. This is managed in that way because the spread of the fire in an informal settlement is quicker than the fire spread in regulated houses.

Response time

From the time the call is received until is communicated via radio, approximately five minutes will have elapsed. The response time for attending a fire in La Carpio is relative. Once the dispatch is done, the response time will depend on the hour, day, weather conditions, the availability of the units, the traffic, the accessibility to the fire, among others.

Fire extinguish time and differentiation between settlements

Several aspects can affect the time it takes to extinguish a fire. According to the firefighters some of the factors that generate more conflict are:

The location. Most of the time, dwellings in informal settlements are not near the streets and if they are, the streets do not have adequate dimensions for the access of fire units. So, attacking a fire entails creating long combinations of hoses.

The structure characteristics. The dimensions, distribution, steadiness, type of fuel material they are made of, among others, will affect the extinguishing time, making it longer or shorter depending on the dwelling features. Most of the houses located in informal settlements have been constructed with flammable materials, such as wood, cardboard, gypsum, plastic, etc. or materials that help the heat transfer like metal sheets. The garbage or dry grass surrounding the dwellings also helps increase the magnitude of the fire. As well, these houses usually have a lack of steadiness so, when the fire is being attacked the houses quickly collapse, turning into heat points that complicate the extinguishing process.

Access to hydric resources. The informal settlements are in non-regulated areas, thus, when the firefighters are going to confront fire emergencies, they mostly do not have hydrants near the zone. If they do, nevertheless, the hydrants may not have a good or constant water supply. Furthermore, if the hydrants are inexistent, the firefighters will depend on the cistern trucks, which usually take more time arriving at the zone resulting in a delay of the fire extinguishing process.

The topography and weather conditions. Most of the time, the informal settlements are on the edges of rivers, on mountain slopes, or in places with rugged topography. Thus, one of the properties that the informal settlements usually have are the steep slopes and the high wind speed. This, along with other weather conditions, produce an easy fire spread.

The stage of the fire. It affects in which stage the fire is when the firefighters arrive. There are four stages in a fire: Ignition, Growing, Developing, and Decreasing. Depending on what stage the fire is found, a technique will be selected to extinguish the fire. Some of these techniques include destroying surrounding informal dwellings to make space and control the fire spread or applying water with pressure or in a mist-like way.

There are several differences between fighting a fire in a suburb zone (regulated houses) and doing it in an informal settlement (non-regulated houses). According to the firefighters, emergencies in the suburbs are easier to manage, due to their housing construction, and security. Meanwhile in the informal settlements, attending emergencies are usually more difficult, due

to the complicated access, the overcrowding and the features of the houses built. Some of the challenges the firefighters face are related to:

Dwelling features. The materials used in housing construction are different. The houses located in suburbs are divided by masonry walls, meanwhile, the informal houses are divided by metal sheets or cardboard, intensifying the likelihood of collapses and fire spread. Also, another characteristic is the architectural distribution. While the regulated houses have a good distribution and planning of the space, the informal houses do not have any planning, thereby more levels or rooms that shelter more families can be found inside the same house without being apparent.

People behavior. Another difference between the suburbs and the informal settlements is the way people behave when it comes to emergency events. In informal settlements, they usually have more aggressive reactions, the firefighters receive insults, threats, thefts, and physical harassment. Firefighter observed this aggressive behavior through some experiences like when the inhabitants forced them out of the truck when they arrived to the site, or that firefighters need to be aware of the fire and keep an eye on the fire tools and units to avoid being robbed. These behaviors interfere with the extinction process. On the other hand, in the suburbs, the people get worried and try to help but not as aggressively as the people in informal settlements and the firefighters are less worried about thefts.

Control of the population. In both places, usually, people get desperate and perform unthinking actions. In informal settlements, however, it is more difficult to control the population. Most of the time and depending on the informal settlement that will be assisted, police support is necessary. Normally, the people in these settlements have more respect for the firefighters than for the police since the firefighters do not interfere in their business meanwhile the police do, and it creates a strained environment. In addition, in both places, people are very collaborative. In the informal settlements, however, they take the extinction job on their hands. The firefighters therefore give them instructions and ask them to work and thus take advantage of these behaviors.

Access to the site. Unlike the informal settlements, the houses located in the suburbs have the advantage of having accessible streets with standard dimensions. This allows the firefighters to locate their fire units near the house on fire. The informal settlements, on the other hand, do not have this condition. They have narrow streets with strong slopes and usually have empirical steps made of soil or wood, increasing the physical effort that the firefighters need to do to reach the fire. Another difficulty the firefighters face is when a fire occurs in informal settlements, since the people living there take their belongings out of their houses and place them in the alleys or streets trying to rescue their stuff, resulting on limiting, even more, the space available to transit.

Rescue and evacuation process. In a house within a suburb, the firefighters can easily rescue the people trapped in the property on fire and they can clearly identify the number of people inhabiting the dwelling. In informal settlements, however, the fire rescue process could be a harder task due to the overcrowding which leads to a required thorough search since the number of people living in a dwelling is unknown. In addition, after the fire, the burned metal sheets and debris

could block the way to the affected zone, making it difficult to find the people in the case of fatalities.

Security. In the suburbs, when a short circuit is reported, the electricity is cut while the issue is being solved. In informal settlements, this cannot be done. If the electricity is cut, the people get mad and that can bring security problems for the firefighters. Usually, when the inhabitants of the informal settlements observe the beginning of a fire and they believe the cause is a short circuit, they begin to throw sand at the electric meter. Then, when the firefighters arrive at the zone, they find the electric meters full of dust.

Strategies and equipment used to fight fires

The main resource used to extinguish fires is the application of water. To confront fires in informal settlements, two fire trucks (each with thousand water gallons) and a paramedic unit are initially dispatched. In case the fire turns more aggressive, reinforcements are requested.

As strategies of extinction, the firefighters use techniques of control and understanding of fire behavior. There are several methods to apply water or air both with pressure or in a mist, each one having a specific function. In informal settlements fires, most of the time the firefighters try to do fire advance control lines, which means destroying informal houses near the fire to make space and eliminate the surrounding fuel. The purpose of this is to control the growth of the fire.

Advice for communities

After a fire, several recommendations are given to the population living in informal settlements, mainly, related to improving electrical connections. Other recommendations given are: to avoid storing chemical products or fuels; avoid having dry grass surrounding the walls; do not leave candles or open flame stoves unattended; improve the gas connections; in case of performing welding jobs, inform to the neighbors or have an extinguisher nearby; avoid leaving children alone; and implement the use of flashlights, among others.

The firefighters say that it is very difficult for these people to abide by the preventive measures given. Usually, they ignore them because they do not have the budget to improve their electrical connections. In fact, they buy low-cost materials, thus bad quality ones. Hence, the best way to improve awareness of the population is through campaigns that show them the importance of prevention. Working with children could be a good way to make the future population conscious, as they will grow knowing the risks to which they may be exposed and how to avoid them. The Fire Department therefore make campaigns, children's camps, prevention speeches, etc. since their main objective is prevention and to spread awareness. Electrical companies also provide information and training about safety electrical connections.

Experience in past events

Finally, the firefighters shared some past experiences in informal settlements fires that allow for understanding of what they face. The majority of the comments received were related to human behavior and how this interferes with the management of the fires. For instance, the people

usually guide the firefighters to the fire through unknown paths. Since they do not have urban planning, all sites are like labyrinths. They help them to get to the site but then, they don't want to go back and therefore hinder their work and risk their lives.

The firefighters also explained that often the residents of these kinds of settlements take advantage of the fires and try to steal their tools. At least twenty-five percent of the firefighters interviewed agreed that children also partook in the stealing process. They also explained that sometimes the dwellers' store hazardous items like buckets with sodium hypochlorite or pool chlorine, consequently, sometimes they receive calls related to chemical reactions that can produce irritation of the respiratory tract.

Fires in informal settlements always are tough experiences for firefighters. They must observe people suffering because they are losing everything they have. The firefighters understand their way of living, and at the end of the fire, they could feel guilty with the job done. Also, they can see how supportive the population can be living there. The neighbors are always very helpful, and they share what they have with the victims to try to minimize their pain for a while. It must be recalled that people in these places are extremely poor, but they help in an altruistic way.

Finally, they consider attending a fire in an informal settlement is an extremely tiring job. This is mainly when they know that there are missing people. They know they need to do the search as fast as possible because, in seconds, all the houses could collapse. The post-fire job is even more tiring due to all the material that must be moved and cool. The metal sheets and the wood are materials that retain heat so the process of cooling the remaining heat points is slow and takes several hours.

The causes, effects and some information given from the firefighters concerning fires in informal settlements are summarized in the following **Figure 7**.

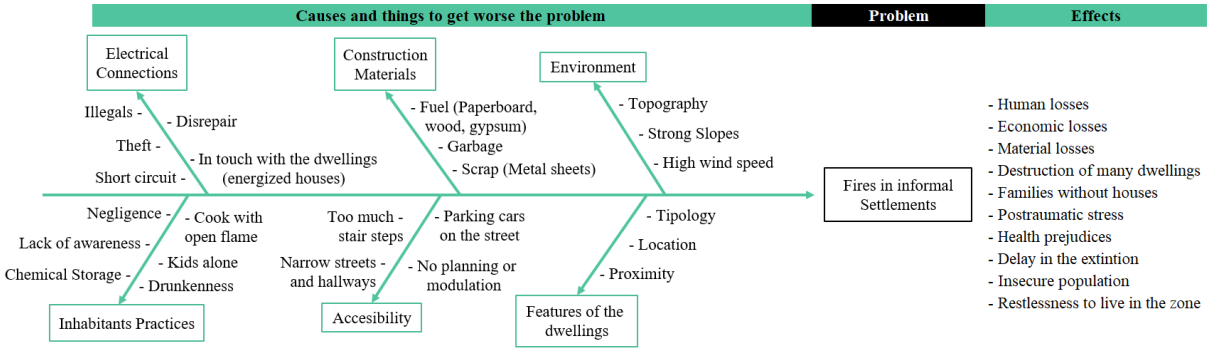


Figure 7. Causes that can affect the fire issue in informal settlements and their effects.

4.1.2 Statements taken from MIVAH interview

The meeting with Mauricio Mora allowed for the understanding of what actions the MIVAH have been developing concerning informal settlements' issues, and what projects are in progress currently in La Carpio. It was inquired if they are developing these projects alone or with other institutions, and what specifically are they trying to solve. The MIVAH is the key actor in the informal settlements problem and solution since it is the rector of the government regarding territorial planning and human settlements (MIVAH, n.d.). Same as the other interviews, the answers will be discussed in the order of the themes showed in **Table 7**.

Actions done

The MIVAH is putting forward a strategy known as "Puente a la Comunidad", a strategy which aims to join the public investments to enhance the conditions of the territories that hold informal settlements. This is done through the merging of local, public, private, non-governmental and community efforts, aiming to boost the urban development and focusing in human security and holistic development. The purpose of the strategy is to build inclusive, safe, resilient and sustainable communities. The strategy has the objective to prioritize 45 districts in which approximately a third of the population is located in extremely poor condition, and the 65% of the population inhabits in informal settlements. The strategy also wants to change the sectoral scheme in which the Government works, switching from public institutions working individually to coordination between them, thus working together to reach the set goals.

Projects and stakeholders

The project developed in La Carpio by the MIVAH consist of an urban improvement plan that will follow five steps, beginning with the geographic characterization of the zone with the information available. In this stage, the number of homes in risk will be identified through roof mapping, then a preliminary polygon positioning will be done over the map to determine which land polygons have the possibility of titling. In this stage, the informal settlement will be divided into blocks. The zones that do not have the possibility of being titled will be used for public space. The second step is the demographic characterization at socioeconomic level. In this stage, the methodology for census implementation will be designed and applied to the community. As well, tracking private, academic, and NGOs resources that could help to maximize the scope of the efforts will be done. The third step is related to an integrated diagnosis at geographical and socioeconomic level, which consists of performing dialogs among the people living in the blocks with titling possibilities. The zones that cannot be titled and have resettlement risks will then be determined and intervened. The fourth step consists of site design and preliminary urban proposal. In this stage, the aim is to define the public streets helping to determine the lots where the people living in risk zones will be relocated, to do this the zones that can be habitable will be densifying through housing projects. This stage also aims to make an interinstitutional plan of the public areas and finally propose experimental policies for this settlement. The last step is the urban improvement plan. In this step, the plan will be validated and implemented, and the experimental policies will be approved.

La Carpio is the only informal settlement with an interinstitutional worktable established through a letter of understanding between several institutions. This allows them to provide attention focused on five main themes, as shown below.

1. Electric transmission: A project carried out by the Instituto Costarricense de Electricidad (ICE, Costa Rican Institute of Electricity), which has the intention of changing the electrical transmission lines.

2. Schools: The Ministerio de Educación Pública (MEP, Ministry of Public Education) is responsible for the schools of La Carpio. The School of La Carpio is already done, and currently, they are working on the development of La Carpio Technical College.

3. Land titling: The Instituto Mixto de Ayuda Social (IMAS, Institute of Social Assistance) is the owner of the land where La Carpio is located, so they are working on giving land titling permissions to the families that have inhabited a house in La Carpio for several years.

4. Drinking water: This process is developed by Acueductos y Alcantarillados (AyA, Aqueducts and Sewers) and it aims to offer drinking water to La Carpio dwellers, however, there is a restriction due to the land titling. It can therefore be resolved once the titling issues are solved.

5. Communal collective bond: A process that is being coordinated by the MIVAH and it seeks to request financing to improve streets, infrastructure, and other projects to organize the territory.

All these themes are discussed with two work groups. In one group, all the institutions and the community have meetings. Here, the institutions inform the community members about the progress of the project and, at the same time, they take notes about the necessities of the population. In this group, the community partakes as a key actor in the community development process. In the other group, the MIVAH works as the coordinator, followed by the San Jose Municipality entity in charge of the land administration, the IMAS as the owner of the land where La Carpio is settled, the Instituto Nacional de Vivienda y Urbanismo (INVU, National Institute of housing and town planning) as the inspector of the town planning, and the AyA and the Fire Department of Costa Rica to manage the pipelines, aqueducts, and the dimensions the community needs to have. In this group, all the technical issues alien to the community are discussed to find the best solution. Here, the institutions are also working on changing the normative technical institutional language into the simplest language, making it easier to comprehend for citizenship.

Risk hierarchy

Currently, the two most important risks in La Carpio informal settlement are the landslides and the fires, due to their high likelihood of occurrence. These two risks intensify mainly in the riverbanks of the settlement. However, fires can occur in other parts of La Carpio even in more formal dwellings due to electrical connections in disrepair as they never followed regulations or quality standards.

MIVAH in fires

The MIVAH is a coordinator and transmitter of public policies. This fire topic is considered new in the country and it is just beginning to appear in the list of subjects to research and to generate guidelines on MIVAH's part. There is not enough information in housing policies and land use to generate these guidelines, but to do it, it is necessary to support the Comisión Nacional de Emergencias (CNE, National Emergency Commission), the Fire Department of Costa Rica, among others, to make the informal settlements resilient to the fires issues. This is a topic within a list of research to do, but at the moment there is not being developed as the main theme.

Regarding the entities that are more involved with this subject, the CNE is one of the main actors since they are focused on the risk prevention field. On the Fire Department of Costa Rica's part, they inform other public institutions about the guidelines and tools that must be prepared to reach better attention of these settlements. For instance, they inform the MSJ about the street dimensions needed, to the AyA the water fluxes the hydrants must have, and other specifications to the corresponding institution that must be deemed to prepare the guidelines mentioned before. The AyA collaborates with the Fire Department by attending their recommendations, as installing bigger pipes, hydrants, and so on, helping the Fire Department to have constant water flow when a fire emergency is triggered. The MIVAH in this subject has a territorial vision, therefore, implementation of housing and urban development policies could help to improve the community features, having, as a result, the improvement of the fire issue this settlement has. The importance of the Municipal involvement must be acknowledged since the municipalities are the ones that have constitutionally the territory administration.

Focusing on cases of informal settlements and informal houses, preventive and resilient actions that fit to the living condition of the families inhabiting these dwellings must be developed. It must be done projects aiming to prevent fires, and others for post-fire stages which include resilience and support for the people affected by professionals in psychology, also, awareness must be made to the population about the risk under they are.

MIVAH objectives

The main objective of MIVAH regarding the informal settlements is to enhance the territory, with the intention of improving the lifestyle of the people living there. Optimistically, there is a possible and feasible solution for the fire issue, but a hard-working strategy will be needed. The MIVAH right now has a working strategy, however, it is still not enough to cover all the national territory, hence, joining efforts with the academy, private actors, municipalities and even the social responsibility of the enterprises could help to attend holistically the situation and find a solution on the whole.

Update database

In the case of La Carpio, all the institutions mentioned above are working beside the MIVAH in a census information gathering that will be applied to all the population living in this settlement by the MSJ. The contemplated variables are related to land use, the number of floors of the dwellings, construction materials, and others. There could be some interest in adding questions

regarding their electrical systems, to know which are the biggest risks for a fire start.

At the same time the census will be applied, a picture from above of the settlement will be taken, in order to know how many houses and families are being surveyed, and to know the population they are working with. The information collected will be compared with the information gathered by the IMAS, along with the settlement history. This process will allow for the determination of which families are still living there and their economic situation. This census will identify all of the population, accounting for all the people inhabiting this settlement and trying not to leave anyone out. To accomplish this, the MIVAH is trying to get support from the community organizations, so they can help them collecting information on weekends, to obtain the data from the people which is more difficult to catch because they work all the week. Once the information of the census is collected, it will be officialized for the institutions and the community. After the census, if any new family entry into the settlement, will be informed that it will not be contemplated in the attention process, since just the population showed in the picture taken with the census will be attended.

4.1.3 La Carpio risk hierarchy

In the meeting performed with Oscar Núñez, he commented about how the risk hierarchy has been changing in the last years. At the beginning the yearly funds saved by the MSJ for disasters were employed mostly in floods and landslides, nowadays a considerable amount of these funds are spent in fire recoveries. In 2019 before the rainy season, a great amount of the money reserved for disasters happening in this season was spent, due to the number of fire emergencies in informal settlements. For example, the fire happened on April 13th, 2019, which left 7 victims and 11 people without housing needed funds for recovery processes and helping the affected community members. This is just one example of several fire cases that occurs in San Jose. In this meeting, Oscar Núñez also commented the MSJ now is implementing the software DesInventar, which allows creating a database of all the disasters of small, medium and large impact occurred in a country or in a specific city. The aim of using this software is to have a damage and loss inventory of the disasters that happened in San Jose, to analyze which ones affect the most the communities and develop plans of how to mitigate this impact.

Previously, the Universidad Nacional de Costa Rica (UNA, Costa Rica National University) made a historic disaster inventory, in which all the disasters that happened in Costa Rica from 1968 until November 2019 are displayed. This inventory is older than the one made by the MSJ which begun recently and only has data from January 2019 to January 2020. The advantage of the inventory performed by the MSJ is it has more detail concerning location. The higher location level it has is neighborhoods, while the UNA inventory only reaches up to districts, following the order of province, canton, district, and neighborhood. Regarding the information shown, in the MSJ inventory for La Carpio from 2019 to this year, there are registered four disasters two of them are fires, one landslide, and one structural collapse. According to this inventory, the higher risk at the moment is the fires, but it is needed more data to draw better conclusions. The information displayed by the UNA database will not be commented, since the information is shown

for the district in general, having sometimes in the description the name of the neighborhood. Besides, searching among the disasters reported from 2017 to 2019, for La Carpio there are only three emergencies, the same shown in the MSJ inventory.

Another source used to search out the risk hierarchy from La Carpio was through the mobile application of the Fire Department of Costa Rica. This application compiles all the emergencies happening in real-time, stores them and makes an inventory. To gather the information of a specific place, it can be used the filter option, but the application does not have an option to export the data, thus the collection of information it had to be done manually. It was compiled the information from 2017 to 2019, here is shown the data collected for 2018 since this is the clearest example of the emergency's behavior through the year in this informal settlement. All the tables done can be found in appendix C.

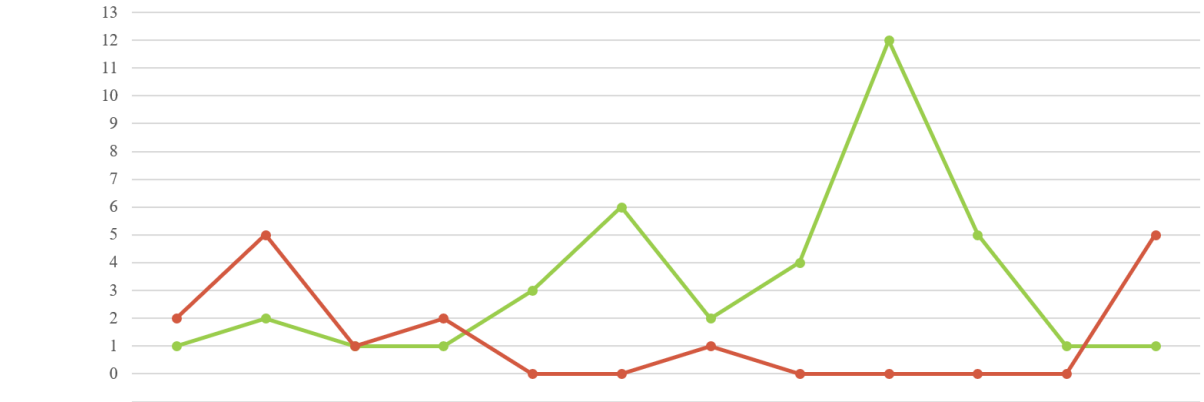
Table 9. Fire calls, La Carpio 2018

Category Month	Waste area	Car/ Motorcycle	Dumps/ Containers	Short -circuit	Grass burnings	Energized elements	LPG leakage	False Alarm	Fire in house	Electrocuted person
January	1	-	-	1	2	1	5	-	-	-
February	-	-	-	2	5	-	4	-	-	-
March	2	-	1	1	1	-	-	-	-	-
April	1	-	-	1	2	-	5	-	1	-
May	2	1	-	3	-	-	9	1	1	-
June	2	-	-	6	-	-	5	-	-	1
July	-	-	-	2	1	-	7	-	-	-
August	1	-	-	4	-	-	-	-	-	-
September	-	-	-	12	-	1	3	-	-	-
October	-	-	-	5	-	-	-	1	-	-
November	-	-	-	1	-	-	4	-	1	-
December	1	-	-	1	5	1	2	1	1	-
Total	10	1	1	39	16	3	44	3	4	1

Source: (Fire Department of Costa Rica Engineering Unit, 2018.)

Table 9 above shows the emergencies attended by the Fire Department in 2018, where it can be observed that grass and waste burnings, short-circuits, and LPG leakages are the most recurrent emergencies throughout the year. The information shown allows to evidence the season of the year affects the likelihood of occurrence of some emergencies. For instance, during the dry season which goes from December to April, the grass and waste burnings are the emergencies that occur the most. In the rainy season which goes from May to November the occurrence of these burnings is lower, and in several months, there are no calls receiving regarding this kind of emergencies. Something similar occurs with the short circuits, though they normally happen throughout the year, in the rainy season the probability of occurrence rises. As can be observed in the table above, during the wet months the number of emergencies for short circuits is higher

than in the dry months. **Figure 8** below depicts the behavior of grass burning and short circuits emergencies throughout 2018. It can be observed the tendency followed depending on the season of the year.



	January	February	March	April	May	June	July	August	September	October	November	December
Short-circuit	1	2	1	1	3	6	2	4	12	5	1	1
Grass burnings	2	5	1	2	0	0	1	0	0	0	0	5

Figure 8. Short circuits and grass burnings in 2018.
Source: Excel.

4.1.4 Other data collected

MIVAH

In 2005 the MIVAH published an update report for settlements in precarious and slum conditions, that document showed physical, geographical and social information from different informal settlements of the country. In La Carpio case, the report shown a total of 5000 families living there, being 1000 Costa Rican families, 2500 foreign families and 1500 mixed families. At that moment, the estimated population was 25,000 inhabitants, being around 50% foreign population, giving to La Carpio the characteristic of being the most binational informal settlement in Costa Rica. Regarding housing conditions, it was reported a total of 3500 dwellings being just 200 houses built in firm constructions and the other 3300 informal houses in bad conditions.

La Carpio was established in 1993, hence in 2005, they were relatively a new informal settlement. Since their early years, this settlement showed several and serious social problems In the report performed by the MIVAH they included some social indicators scaled from 0 to 5, being 0 an inexistent issue and 5 the highest seriousness rank of the problem. La Carpio scored 3 in domestic violence, 4 in drug addiction level, 3 in delinquency level, 3 in prostitution level, 5 in drug selling level. Nowadays the situation of these social risks is unknown since in recent reports there is no information regarding this matter.

In 2013 the MIVAH made an update of their database of informal settlements inside the GAM for the period 2011 – 2013, in this document they reported for La Carpio a total of 39,000 inhabitants and 4500 dwellings. This results in an average of nine people per house approximately.

This document only reported the year of establishment of the settlement, the total of houses and inhabitants, thus, there is no more information available or updated for this period. The only data updated and published by the MIVAH was the area of La Carpio which is approximately 0.46 km2, this information was reported in 2019 in a PowerPoint presentation for La Carpio, Urban Improvement Plan.

INEC

In 2011 the INEC performed the X National Population Census and VI of housing, from this census the INEC published a report showing the main indicators about informal settlements. In this report, the sociodemographic information of all the settlements registered in the INEC database was displayed. Though this information is out-of-date, it can be used to make a general description of the settlement. For La Carpio, the census reported a total population of 19,035 showing a low rate of elderly people, being just 2.40% equivalent to 457 people approximately. There is an average of 2.5 children per woman, being the population between 0 to 14 years around one-third of the overall population of the settlement with 34.40%. The population between 15 to 64 is the greater percentage being 63.20%. Of the whole population, 11.60% of people reported having at least one disability. **Table 10** summarize the data displayed above.

Table 10. Population data obtained by the INEC

Total population	19,035
% Population between 0-14 years	34.40%
% Population between 15-64 years	63.20%
% Population with 65 years and more	2.40%
Average of kids per woman	2.50
% Population with at least one disability	11.60%

Source: INEC, 2011.

Concerning to education and technology access, the assistance to regular education is 61.60%, the average of schooling is 6.7 years. The 3.60% of the population is illiterate, from the overall population, at least 28.00% of them have used the internet one time, with 69.00% of the people having cellphone. Regarding the labor force of La Carpio, the occupancy rate is 56.3, of this around 7031 people are employed while only 326 people are unemployed, in general the unemployment rate is 4.4 in this settlement. From all the population of La Carpio the 41.10% is out of the labor force range, and the 76.30% of the population have salary. **Table 11** summarize the data displayed above.

Table 11. Employment and education data obtained by the INEC

% Assistance to regular education	61.60%
Average Schooling	6.7
% Population illiterate	3.60%
% Population that used internet	28.00%
% Population that used cellphone	69.00%
Occupancy rate	56.3
Population employed	7031
Population unemployed	326
Open unemployment rate	4.4
% Population out of labor force	41.10%
% Population with salary	76.30%

Source: INEC, 2011.

In La Carpio there is a total of 4700 homes, with an average of four dwellers per home, however, 27.90% of the population lives in overcrowding conditions. From all the houses built in this settlement 19.60% are rented houses, 3.30% are borrowed, 66.00% are in precarious conditions, and only 9.10% are own houses totally paid. This house belonging condition could psychologically affect the response of the inhabitants when confronting an emergency, since, it would not be the same response protecting their own house against another that is not. Regarding house features 100% of these have electricity, 99.10% receive water from aqueducts, 14.20% have ceiling but just 3% of them have sewerage. About the house conditions, 26.50% are in a good state, 50.00% are in a regular state, and the remaining 23.50% are in disrepair. **Table 12** summarize the data displayed above.

Table 12. Dwellings data obtained by the INEC

Total homes	4700
Average of dwellers per home	4
% Overcrowded dwellings according to rooms	27.90%
% Rented homes	19.60%
% Borrowed homes	3.30%
% Precarious homes	66.00%
% Own housing totally paid	9.10%
% Dwellings with electricity	100.00%
% Dwellings with aqueduct water	99.10%
% Dwellings with ceiling	14.20%
% Dwellings with sewerage	3.00%
% Dwellings in good condition	26.50%
% Dwellings in regular condition	50.00%
% Dwellings in disrepair	23.50%

Source: INEC, 2011.

MSJ

The first contact with the MSJ allowed obtaining sundry vectors with different data related to the informal settlement in study, one of these vectors shows the land division they use for the nine sectors of La Carpio. **Figure 9** shows several shapefiles joined from La Carpio, which allows observing the land lot division, key buildings, and other features that helps to describe what can be found there. The red polygon corresponds to Roble Norte, this vector permitted to determine the area of the sector which is around 0.076 km2. Moreover, it shows some key places inside La Carpio, for instance the green lot above to the left is the new School of La Carpio. Next to the main street, the yellow point marks the location of CODECA, the community development council of La Carpio, and the orange footprint is the Tobias Bolaños Airport, property of the government.

The MSJ apprise to the author they are the intellectual owners of all the data shared. This information is strictly a graphic representation of the Geobase data of the MSJ at the time of the vector elaboration. This information is subject to the proper updates of the dynamic data; thus, this information is indicative, not definitive.

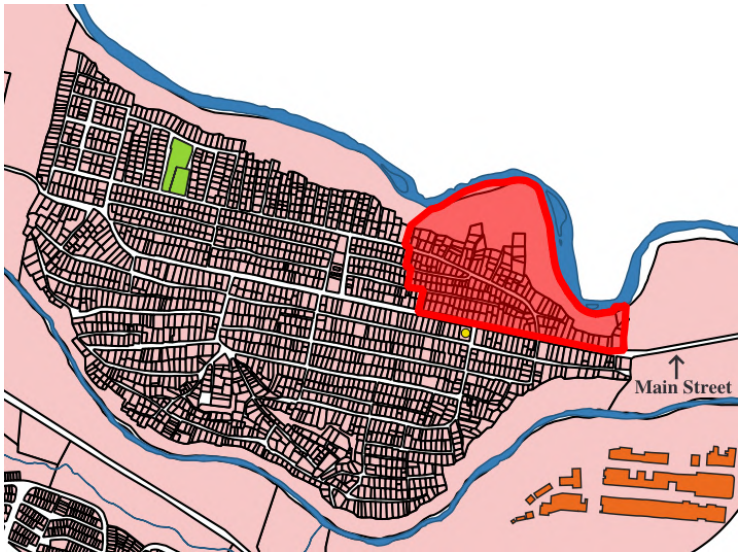


Figure 9. La Carpio lot division.
Source: MSJ, QGIS software.

In May 2019, the MSJ published in their municipal newsletter some information of San José neighborhoods included among them, La Carpio. In this bulletin, the municipality report an area for La Carpio of 0.35 km2, with a population density of 52,360 inhabitants per square kilometer, thus the total population of La Carpio according to the MSJ is 18,326 inhabitants, being the biggest informal settlement of the country. Of the total population, 34.80% are people within a range age of 0 to 14 years old, the people between 15 to 64 years old comprehend the 63.30% and the elderly people encompass only 1.80% of the whole population. Regarding housing features the newsletter only displays the total homes, being 4571 with an average of four people per home. Although the information was printed in the 2019 municipal newsletter, there is no date for the information showed, therefore the author does not know how old or recent is the information displayed.

The recent efforts performed by the MSJ are related to the urban improvement plan mentioned before. Currently, the MSJ is working on the establishment and regulation of the roads that will divide La Carpio and the demographic data collection of the site. At the end of 2019, the MSJ carried out a census in La Carpio in order to grasp the information needed for the development of this new plan, the author asked the MSJ for this information but there was no response back. Concerning to the regulation of the roads, some of these floor plans are in process of approval by the Colegio Federado de Ingenieros y Arquitectos de Costa Rica (CFIA, Federated College of Engineers and Architects of Costa Rica), this will be the first step to reach the land planning of La Carpio.

INCAE

In 2018 the Centro Latinoamericano para la Competitividad y el Desarrollo Sostenible (CLACDS, Latin American Center for Competitiveness and Sustainable Development) part of the INCAE business school, performed a study related to the collective and sustainable well-being of La

Carpio informal settlement. This study was done with the collaboration of the Sifais. Some indicators included in this study were compared with all the districts of San José canton, allowing to observe the differences between the zones.

The total population registered in La Carpio is around 18,326 and the area of this settlement is 0.35 km2. Of the entire population, just 9.10% of the people are owners of their house, also from the dwellings built in La Carpio, 24.30% are houses in disrepair and 6.00% of them are hovels. In this settlement the 7.00% of the houses have access to internet, and 90.30% of the people have cellphones. Concerning the earnings and education, in La Carpio an important source of income is the remittances, 35.30% of the houses receive this kind of revenue, being the highest among all the districts. The unemployment rate and the illiteracy percentage are the highest as well in comparison to other San Jose districts with 4.5 and 8.3% respectively.

CNFL

On the part of the electricity companies, the CNFL is now implementing the grouped measurement system. The main objective of this program is to decrease the non-technical energy losses, providing alternatives for safe connections to the clients with illegal connections whose consumptions are not billed. Furthermore, the project aims to get rid of the constant fire risks this type of connection entails. Also, customers will know in real-time their consumption since a display will be installed at the entrance of their homes. This will allow people to determine how much money they want to spend on this service (elmundo.cr, 2018).

According to the CNFL, in La Carpio four of these grouped measurement systems have been implemented, three of them with measurement panels and the remaining one concentric. In total there are 79 panels (costumers) with this service. In the Filadelfia street, there are 30 measurement panels, at the Pequeña Gran Ciudad sector there are 16 measurement panels, in Baldosas street there are 9 measurement panels, and in Sifais there are 24 costumers with a concentric measurement system. Currently, CNFL works in a project in Las Gradas, where 250 concentric measurements will be implemented, being 250 customers benefited. The project intends to start in June 2020 and end around June 2021.

Atlas and others

The Atlas of Costa Rica has several layers with information of overall features of the country, in this research the author merged the Atlas, INEC and AyA layers to obtain other features of the study zone. The layers used by the Atlas were those correspondents to provinces, fire risk, and rivers, information helping to understand characteristics that could increase the fire risk, as well as helping to better address the future implementation of fire safety plans. From the INEC, the informal settlements map layer was used, and from the AyA the layer which has the location of the hydrants in La Carpio. **Figure 10** allows observing all these layers together.

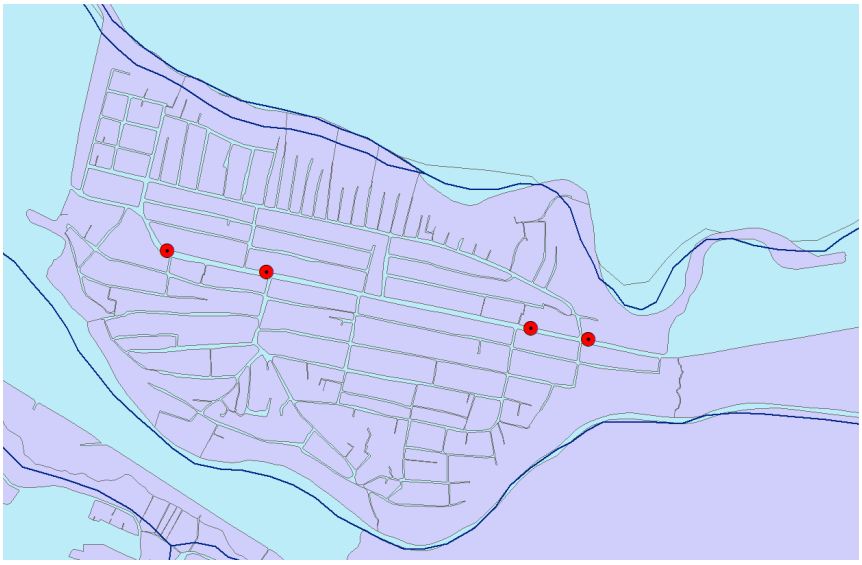


Figure 10. Data collected through GIS vectors
Source: Atlas CR, INEC, AyA, ArcMap.

The layers used to characterize the informal settlement had scarce information attached. The blue lines are the rivers surrounding the settlement, at the top there is the Virilla river and at the bottom, there is the Torres river. The purple footprint is the informal settlement according to the INEC layer, it should be noted La Carpio is among the two rivers and starts at the beginning of the main street. The light blue layer represents the fire risk but is more related to the wind speed and the ease of fire spreading. For this zone, the fire risk is high to very high. The wind speed for high risk is between 3 – 5 m/s, and for very high risk is over 7 m/s, it must be recalled La Carpio has canyons in both edges, thus having high wind speeds which can increase fire spread in case of an emergency. The red points show where are located the four hydrants throughout La Carpio, but there is no information attached to this layer. In order to obtain other details of these hydrants, the map done by the Infraestructura de Datos Espaciales de Bomberos (IDEB, Firefighters Spatial Data Infrastructure) was consulted. The IDEB is part of the Fire Department of Costa Rica, in this map information regarding emergencies, fire stations, hydrants detail, and so forth can be found. The only feature obtained in the IDEB map regarding the hydrants was they are in good condition.

Another source consulted was the CFIA, but the author does not receive an answer back from them. Also, the new data collected from MIVAH census, carried out at the end of 2019 in La Carpio was requested, but same as with the CFIA, the author does not receive an answer.

4.2 Roble Norte

In this subsection the information collected from Roble Norte sector will be shown. Here the field visits were performed and focused mainly in Las Gradas sector, being the zone inside the sector with the highest probability of having fires. Also, another information gather from other

institutions will be displayed allowing to describe a little bit this sector.

4.2.1 Field visits

The field visits performed allowed for the observation of how La Carpio is distributed, its physical characteristics and the conditions under which the people live. The first visit performed allowed to recognize the site and to obtain the map they use to divide the informal settlement. The boundaries of the sectors used by the community are depicted in the figure below. **Figure 12** outlines the nine sectors of La Carpio according to the information obtained from CODECA members. It must be understood that this distribution is not formal, it is just a guide for the population inhabiting the settlement and is a document that allows having a little bit of control of the physical spaces. It does not however have any legal value. **Figure 11** shows an scheme of the process followed for this visit.

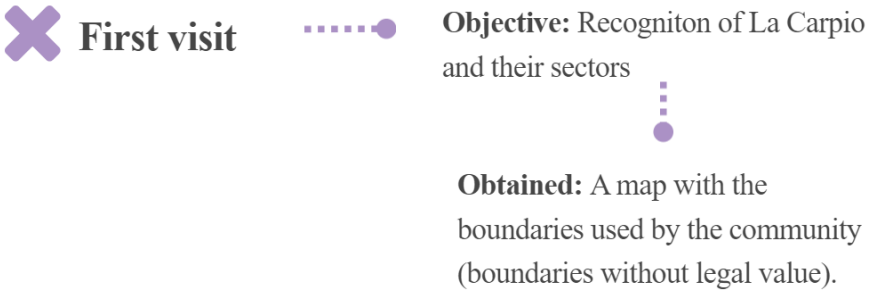


Figure 11. Scheme of the first visit.

Figure 12. Boundaries of La Carpio sectors according to CODECA.
Source: CODECA.

In the second field visit, the photographic record of Roble Norte was performed. The focus was mainly on the zone called “Las Gradas”, located at the north of the sector, due to having the worst housing conditions and the higher likelihood of fire in Roble Norte. This zone is called Las Gradas due to the number of steps in the alley that carry out to the end of the zone. There are approximately 200 steps. The images herein will be linked to an approximate location using google maps. **Figure 13** below show the enumerated points, with approximations of where the author stopped to take the pictures. These pictures will depict the zone distribution and the construction features detected during the visit, such as house dimensions, number of floors, construction materials, electrical connections, among others.

Figure 13. Approximated points where the pictures were taken.
Source: Google Maps.

It should be noted that the specific locations are not certain since the georeferentiation details of the pictures are not available. Taking a cellphone out to review the geographical coordinates was avoided by recommendation of the police officers. Another detail that must be mentioned about Las Gradas is regarding the number of alleys and its lack of representation on the map, which makes it even more difficult to identify the extension and complexity of the zone. In some of the pictures, a wood meter can be observed which was used to have a scale of the picture and an estimate of the streets’ measurements. In the interview with Mauricio Mora representant of the MIVAH, it was mentioned that the MIVAH performed the data collection of the street measurements in La Carpio, but Las Gradas was disregarded since this zone is not allowed to obtain land titling permission, therefore in the future, the MIVAH will relocate the families inhabiting in this specific zone.

Description of the pictures taken

At *point 1* in **Figure 14**, the wood meter allows estimating the street width which is around

four meters. Though the fire units are usually around 2.5 meters wide and fit in the street, it is difficult to access this point, mainly because of two reasons. First, as it can be observed, there are several cars parked on the street edge, preventing the passage of the fire units. The other reason is concerning the turning radius needed since the street does not have enough dimension to allow entry of the units. Hence, if a fire starts, the firefighters would need a large combination of hoses.

Figure 14. Picture at point 1.

Point 2 in **Figure 15** shows the entrance of Las Gradas. This is the wider space of this zone having around 3.20 meters, as the deeper into the settlement the people walk, the narrower the streets became. In La Carpio, the houses around main or secondary streets are a little bit more planned and standardized. This picture illustrates the kind of houses that can be found near secondary streets. It can be seen that most of these dwellings have masonry walls or steel structures. These houses also have more distance between them, preventing the faster spread of the fire in case of an emergency event. Though the space between the dwellings can help to avoid the heat radiation, the inhabitants must be careful, since metal sheets facades can be heated quickly.

Figure 15. Picture at point 2.

Point 3 in **Figure 16** depicts the beginning of Las Gradas. Here, the street is reduced from 3.20 meters to 1.20 meters. On the left side of this path, there are rocks, a melamine board, and plastic and metal sheets, some of which can be fuel for a developing fire. These materials are near a house with a metal sheet façade. In a fire event, they can easily catch fire by heat transfer. On the left side of the steps, there is a slope, while on the right side, there are metal tubes standing and some plastic water pipes. This combined with the difficulty to see during a fire event due to the smoke and fire safety equipment the firefighters put on their faces, can make it harder to enter the zone and reach the fire. All these obstacles, steps, and uneven surfaces can also make the firefighters fall and hurt themselves, resulting in a higher fire response time, provoking a bigger affectation in dwellings and people inhabiting the burning area.

Figure 16. Picture at point 3.

At *point 4*, **Figure 17** also illustrates the obstacles and uneven surfaces mentioned at point 3. This issue is repeatable alongside the alleys and it will be observed in the next images. In this figure, a bunch of cables without order, called spaghetti wires, can be seen at the roof level. These are made from different gauge and kind of cables. In the interview with the firefighters, they explained that in the informal settlements the population use any kind of cable like telephone, coaxial, among others, and make cable splice between different wire gauges, rising the likelihood of a short circuit. In this interview, they also explain how the inhabitants obtain electricity. First, they peel the main cable located at the electric poles, then they attached metal clothes hooks to the peel cable to transfer the electricity and then, transfer the electricity to their dwellings with cables. It must be noted they do not use tubes to protect their electrical installations. This is a ceaseless hazard in the rainy season.

Figure 17. Picture at point 4.

At *point 5*, **Figure 18** shows examples of the kind of houses built when one goes deeper in the alley. At this point, the predominant material of the houses are metal sheets and wood pieces. In **Figure 18(a)**, the houses are built with different kinds of sheets used usually for roof construction. Also, the house at the bottom beside the steps has a low ceiling, which can injure the pedestrians or firefighters in case of emergency. In **Figure 18(b)**, a masonry house with several floors and a mixture of building materials can be observed. This house does not look like it has construction design, thus, it can be risky to live in or around here. The steadiness of this building its doubtful and, in a seismic country like Costa Rica, it could be under constant risk of collapse. **Figure 18**, the two pictures show rocks, brick pieces, and plastic boxes over the roofs. These are used to prevent the wind uplifting the roof sheets out. These however could be a risk for the people living there, since the wind speed in this kind of topography is usually high.

Besides the materials and construction characteristics, the cables near the houses imply a constant risk for the dwellers. In the interviews carried out with the firefighters, they explained sometimes these cables, due to the wind speed, begins to rub the metal sheets, then the cables begin to peel. When they lose they plastic protection can energize the house, triggering a fire.

(a) **(b)**

Figure 18. Picture at point 5.

At *point 6*, there is a division of the path, splitting into three alleys. The first one is illustrated in

Figure 19(a). This alley reduces in width from 1.20 meters to approximately 0.70 meters. On the left side, there is a house at a lower level and, on the right side, there is a piece of wood, pieces of metal, vegetation, electrical wires, and a concrete pole. All these elements are inclined thus hampering the path, making the available space to transit shorter. This could get lit in the case of a fire and it may fall and therefore can affect the house on the lower level and completely block the path. At the bottom of the same image, a wooden post with two wires can be seen. This is an example of how they extend their main lines to the houses deeper in Las Gradas. **Figure 19(b)**, meanwhile, depicts a house of several levels constructed with low-quality materials. This could be a potential risk for a fire since it is constructed with flammable materials and the metal sheets could transfer the heat through radiation to the houses surrounding them. The firefighters mentioned in the interviews that, in this kind of buildings, several families live inside, as in most of the houses. The houses are usually divided by rooms where families inhabit, hence, in one house, three families or more can live. As this house illustrates, it is becoming common to construct houses of several floors. Horizontal construction is more difficult since they do not have enough space to keep growing, thus the solution embraced is constructing buildings with more levels. **Figure 19(c)**, the other two paths can be observed, with one going up. This path leads to other parts of the settlement and to the exit by the parallel street. The other one, which is going down, leads to the end of the Las Gradas zone, where the rest of the houses are located, and where the Virilla river can be found. The author followed the path down the street in order to get more information about the settlement, then the path up the street was followed to go out by the parallel street.

(a) (b) (c)

Figure 19. Picture at point 6.

At *point 7*, **Figure 20** shows the street going down. This road has an approximate width of 2.60 meters. It can be observed that the street has an inclination, but it is not regular across the street. In here at the end of the inclined street, there is a step made of bricks. On this step, a plastic water pipe is located and there is an anchorage beside the step. This can be dangerous for normal transit since someone could stumble and fall. Regarding a fire event, this can be a problem for the firefighters, since they do not know the place where they are working, and they can get hurt because of the uneven surface of the streets and with all the things hindering the path.

Figure 20. Picture at point 7.

At *point 8* in **Figure 21**, there is another street, with an approximate width of 2.00 meters. This street has similar characteristics to the previous streets described, with empirical steps and uneven surfaces. This one leads to other parts of the zone where similar houses can be found. In the deepest zones of the settlement, the features of the streets are quite similar, with holes, obstacles, irregular surfaces, and so forth. Also, in these zones, the fire likelihood is higher than in the rest of the settlement, thus, all these paths are always a risk for the fire units, when it comes to attend fire emergencies.

Figure 21. Picture at point 8.

Figure 22 below illustrates *point 9*. The two images shown in this figure were taken in the same position, looking in both directions. **Figure 22(a)** is looking back from where the author was walking, and it can be observed that the width of the path is around 1.00 meter. Here, as in previous descriptions, the alley has the same features, as uneven surfaces, plastic water pipes, disordered steps, etc. In **Figure 22(b)**, the picture is looking forward, and the width of the alley is around 1.20 meters. On the left side, there is a gap which the dwellers use something like a

wooden pallet to avoid falling and to entering their houses. All these features can be dangerous in case of fire. If the firefighters enter to extinguish a fire, they can easily fall in these gaps or even fall due to the characteristics of the alleys. At this point, the distance between the dwellings is very short, in front of the dwellings, there is approximately 1.50 meters and sometimes less space. This allows for a faster heat transference and therefore an easier fire spread. In addition to the lack of space, in fire events, the people usually put their belongings at the side of the alley, making even more difficult to transit.

(a) **(b)**

Figure 22. Picture at point 9.

At *point 10*, **Figure 23** depicts a passageway that leads to more dwellings. The width of this path is around 1.10 meters. At the side of the steps, there are bags with coarse aggregate material for concrete making. As mentioned with past pictures, it can be observed that the main construction materials for houses are metal sheets, wood pieces and sometimes masonry or concrete. In the middle of this path, besides the steps, there is a little balcony made with wood. All of these unplanned structures combined with the bad conditions of the paths hinders the entry of rescue and fire response teams. These pictures give to the reader an idea of the configuration of the buildings and their construction features. In this zone of the informal settlement, most of the characteristics are repeatable. For instance, at the top of the image, electric wires going down can be seen. This is to allow more people to get electricity, using similar configurations like the one shown in **Figure 19(a)**..

Figure 23. Picture at point 10.

Figure 24 at *point 11* shows the irregular surface of the path at this point. This picture allows the understanding how the people constructed the slabs along the settlement. They simply casted the concrete over the soil, avoiding using the proper procedure and techniques. It can also be observed that the people in charge of doing this pathway left a hole under the slab. Over this hole, there is something like a grid, and it looks like makeshift sewage. On the right side of the image, a height structure made from steel tubes can be seen. It does not appear straight but in this kind of settlements, all the things are made under informality. This picture also illustrates the issue of the electrical connections mentioned before. At the top of the image, a bunch of cables can be seen which are empirically spliced, thus having the constant risk of a short circuit.

Figure 24. Picture at point 11.

Finally, the last picture taken in "Las Gradas" was at *point 12*. **Figure 25** shows a big amount of garbage at the entrance of this zone. This is something recurrent in La Carpio. In all the streets,

garbage can be found in heaps, creating an obstacle for free transit. In this case, the garbage is covering around half of the alley, which makes difficult to access the site. Furthermore, in case of fire, this garbage could work as fuel, creating heat points, obstructing the hallways, and making it more difficult to enter and extinguish the fire.

Figure 25. Picture at point 12.

Taking into account Las Gradas was crucial for this research since it is the sector the most prone of Roble Norte to experiencing fires, and because it depicts the real characteristics of the dwellings and the deplorable conditions under the people inhabiting in this informal settlement live. These pictures allowed for the observation of physical features, the distributions of the zone, and to understand how the people living there are in constant risk of fire. The people inhabiting these zones are usually poor and they have high probabilities of losing everything in a fire event. This situation is stressful for them, and this can be observed in their response actions when it comes to confronting fires. As mentioned before, there is a difference from the detection and firefighting to recovery when comparing the people living in suburbs against those in informal settlements. In addition to the pictures of Las Gradas, other photos from Roble Norte were taken. **Figure 26** below shows the approximate location points that were photographed.

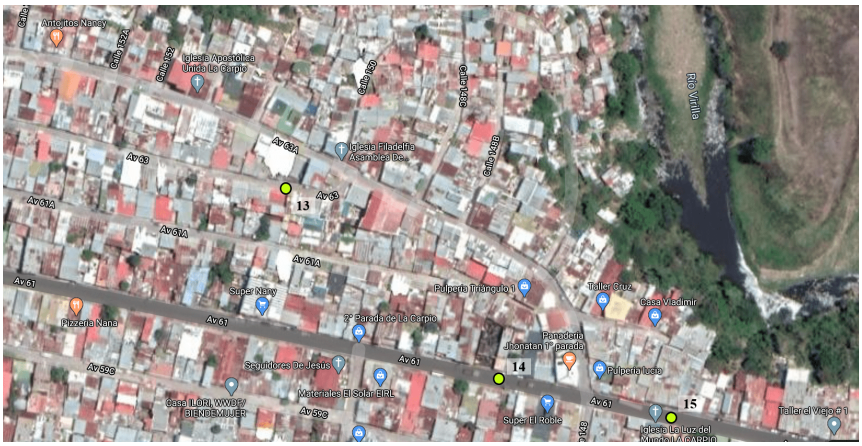


Figure 26. Approximated location points for Roble Norte pictures

At *point 13*, **Figure 27** shows the avenue 63, where the width of the street is approximately 2.60

meters which does not allow either the entry of a fire truck. Moreover, in this street there are no hydrants near. The hydrants are located along the avenue 61, therefore in case of fire, from the nearest hydrant to the entry of this avenue, it will be necessary to extend around 220 meters of hoses.

Figure 27. Picture at point 13.

At *point 14* **Figure 28** shows avenue 61, the main road of La Carpio. This one has a width of 7.00 meters. This road is used by the firefighters to park their fire trucks when a fire is happening in this settlement, due to is the only road with hydrants and with enough space to place them. In **Figure 26** at point 14, the footprint of the fire which happened on April 13th in La Carpio can be seen. This fire did not affect more houses due to their proximity to the main road and thus the hydrants, letting the firefighters extinguish the fire rapidly. Another thing that helped to extinguish the fire quickly was due to the fire happen at dawn, so the water flow was constant.

Figure 28. Picture at point 14.

The last picture taken was on the same road on avenue 61 but at the entrance of La Carpio. At *point 15* in **Figure 29**, the road has the same width, around 7.00 meters. This picture illustrates one of the main problems when entering to this settlement. In the interviews performed with the firefighters, they mentioned that access is complicated since the trucks or buses hinder the entry, and when the firefighters come, they do not let them pass and they do not give them priority. Additionally, most of the time, there are trucks from electricity or communication companies, which also block the path.

Figure 29. Picture at point 15.

Figure 30 shows a schematic of the objective of the visit, which tools were used and the general information that must be considered, then **Figure 31** shows a summary of the information collected.

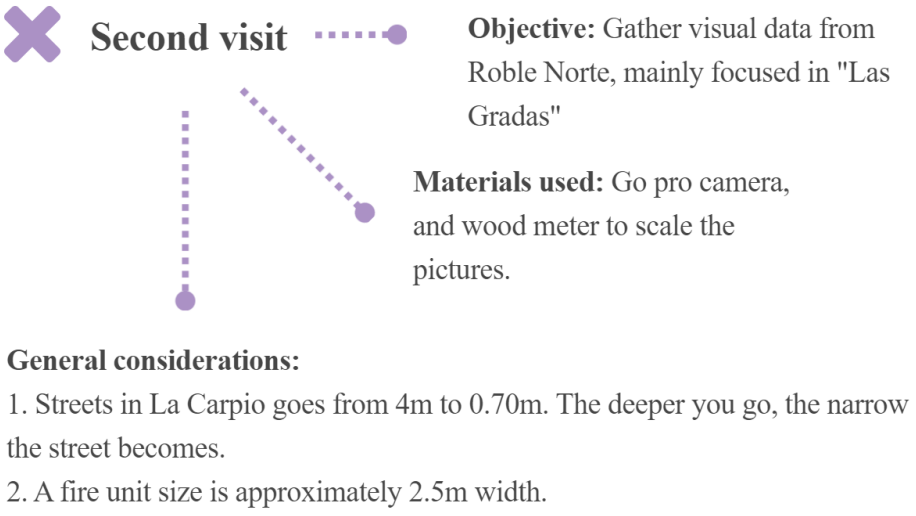


Figure 30. Scheme of the second visit.

Characteristics found

Access to the settlement:

1. Trucks and buses hinder the main entry, impeding the access of the fire units.
2. Even if the streets are wide, the fire units cannot enter due to: cars parked, not enough space for turning radius, the streets begin to get narrower.
3. The mentioned above entails, as a result, a large combination of hoses to reach the fire.

House features:

1. Steel structures and masonry walls mainly on the streets outside.
2. Wood and metal sheets facades.
3. Houses with several floors and made with a mixture of construction materials.

Site features:

1. Several obstacles on the floor, like plastic water pipes, steps made from soil, wood, etc.
2. Uneven surfaces and sewer holes in the middle of the alleys.
3. Electrical connections exposed, in deplorable condition, with splices made from different wire gauges. Spaghetti wires.
3. Houses with several floors and made with a mixture of construction materials.

Figure 31. Summary of the information gathered.

4.2.2 Other data collected

Before mention details of the information collected, it must be noted Roble Norte does not have legal boundaries defined, therefore in this section the information gathered could vary since every institution have their own delimitation of the sectors. In the majority of the cases, a picture of the map delimitation used by the institution reporting the data will be attached, mainly to inform the reader which area has been considered.

INEC

The information collected by the INEC for this specific zone was purchased, since not all the information they collect with the census is public, as explained in the methodology. With the census performed in 2011, the INEC gathered information regarding several aspects, for this case study the variables bought were related to the predominant materials of the dwellings, their cooking methods and the number of inhabitants of the zone. It was permitted to acquire five variables but one of them is reiterative, thus it will not be commented. **Figure 32** bellow depicts the delimitation of Roble Norte used by the INEC.

For Roble Norte sector a total of 845 dwellings were detected, these houses use as predominant materials in the exterior walls, masonry or bricks in 44.85%, materials as zinc sheets, adobe, etc. in 32.07%, wood in 13.49%, in lower percentages other materials like wood-cement or asbestos cement-cement mixtures in 3.67%, Fibrolit, Ricalit (asbestos cement sheets) in 2.60%, wasted materials in 2.01% and prefabricated materials or tiles in 1.30%. Regarding the predominant material in the roof the 99.41% of the dwellings use zinc sheets, 0.47% of them use clay tiles and the least used materials for roofs are in 0.12% asbestos cement sheets.

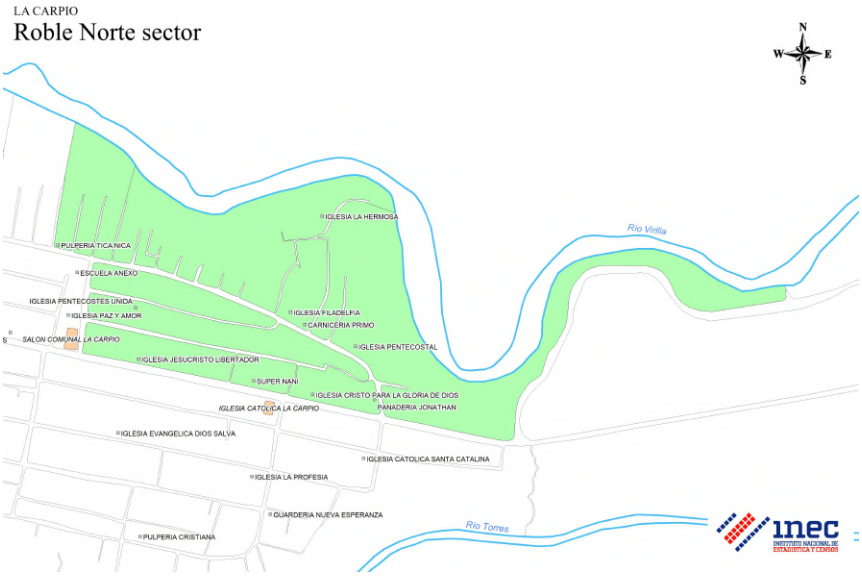


Figure 32. Roble Norte delimitation according to INEC
Source: INEC.

The main intention of this research is to understand the necessities and features of the informal settlements, in order to find a solution that can improve the fire safety of these zones. It is significant for this study to understand which the main fuels are used by the people when cooking. According to the INEC, 49.82% of the houses cook with LPG gas, followed by 47.69% using electric stoves, only 1.30% use in their homes open flame cooking methods with firewood or coal, and the remaining percentage are people who reported do not cook in their homes.

The data of the people inhabiting in Roble Norte was reported by the INEC according to the habitual residents of the house, consequently, the author made the calculations and obtained a total of 3539 inhabitants, it must be deem could be more inhabitants in the settlement, since the calculation was done using 10 in the category *"10 and more"*, hence the number of inhabitants reported is the minimum that can be living in this sector. **Table 13** show the data displayed by the INEC and the calculations done.

Table 13. Habitual residents in the dwellings

Habitual residents	Homes	Dwellers per homes
1	54	54
2	122	244
3	149	447
4	188	752
5	152	760
6	83	498
7	44	308
8	20	160
9	14	126
10 and more	19	190
Total	**845**	**3,539**

Source: (INEC, 2011.)

MIVAH

In the updated database of informal settlements inside the GAM period 2011-2013 published by the MIVAH, they report information of several settlements. In the case of La Carpio, the report gave overall details of the settlement and some data about the nine sectors that compose it. Addressing the Roble Norte sector, the database reported this sector was established in 1995, it has around 800 dwellings and a total population of 4000 inhabitants, resulting in an average of 5 people per home. The data obtained by the MIVAH does not have maps or pictures of the delimitations they use for the information gathering in this informal settlement.

La Carpio health center

La Carpio health center also contributed given the data they have for Roble Norte but having the particularity they call this zone Roble 1. This zone is delimitated differently than other delimitations used by the community members or other public institutions as the INEC and the IMAS. **Figure 33** was shared via WhatsApp by one member of the health center and shows the map with the delimitations they used to collect the information. In this map the sector painted in red at the right superior corner is the corresponding to Roble 1. **Figure 34** shows the interpretation of the author using the colored map and the sketches given by members of the health center (see annexes 1 to 4). It should be noted **figure 33** has numbers on the colored areas, but they are illegible. The sketches are also confusing, it is difficult for the author to fully understand the segregation of the land used by the health center for collecting information.

Figure 33. Delimitation map used by the health center
Source: La Carpio health center.

Figure 34. Map interpretation done by the author.
Source: Google Maps.

The data given by La Carpio health center is fairly recent, the information was collected for the period 2017-2018. Here they reported a number of 623 dwellings and a total population of 5218 inhabitants, having an average of people per dwelling around 8.4. One member of the health center commented this information could be more approximated to the reality since the people usually admit them and are more open due to being members of the health field. This information cannot be confirmed, further research must be done to validate it.

IMAS

When consulting the IMAS about the information they have of La Carpio informal settlement and Roble Norte sector, they sent a spreadsheet with sociodemographic variables stored in their database. These variables are similar to the ones commented before as education, employment, house conditions, house tenancy, among others. This information is not useful for this research since there is information about families who approach this institution to get economical help. The IMAS does not have general statistical data that can be used to describe the study zone; thus, it will be neglected in this research. The IMAS has a delimitation in their database, this one is depicted in **figure 35**.

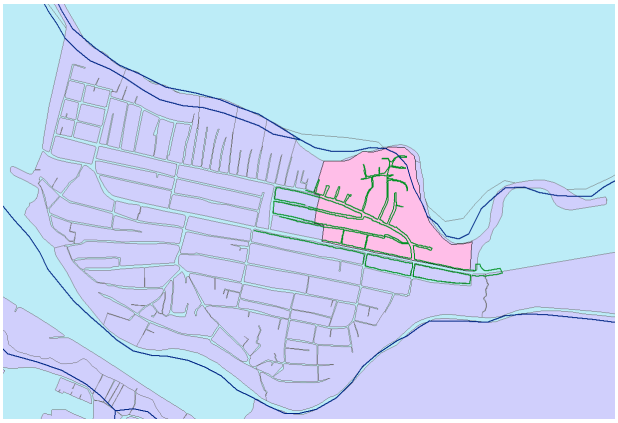


Figure 35. Roble Norte map according to IMAS.
Source: IMAS.

5. International experiences

Several countries around the world have implemented fire safety measures, in order to prevent human and material losses due to large scale fires in their informal settlements. Some of the measures applied in these countries are commented in this section as part of the last specific objective settled at the beginning. These measurements maybe could help to address in a short term or give temporary solutions to the Roble Norte fire issue.

Lebanon

In Lebanon, there are located Syrian refugee camps, where the fire is perceived as one of the two most concerning risks by Lebanese displaced people. In 2016 Operation Florian, a UK registered fire and rescue service humanitarian aid charity organization, performed a risk assessment in this zone, revealing there is scarce knowledge regarding fire safety. Operation Florian proposed and approach to improve fire safety, including community prevention and awareness activities. (ARUP, 2018)

The Lebanon Shelter Cluster, a group of humanitarian organizations, formed a committee that developed Guidelines for Fire Prevention, Preparedness, and Response (FPPR), here specifically guidance for Informal settlements was included. This technical committee was led by Save the Children (SCI) Lebanon, a non-governmental global organization that promotes children's rights provides relief and supports vulnerable Lebanese and Syrian refugee children in Lebanon. (ARUP, 2018)

SCI Lebanon developed fire safety training tools and resources for implementing partners, with the help of UNHCR (United Nations High Commissioner for Refugees). These courses incorporated the guidance and distribution of fire safety resources and training for the communities. SCI Lebanon also provided fire safety resources as smoke alarms, fire extinguishers, and firefighting tools to the inhabitants of the refugee camps. Also, they trained adults and children regarding how to prevent, prepare and respond to fire in their homes and communities. (ARUP, 2018)

India - New Delhi

Informal settlements of New Delhi have similar features to other settlements located in other countries around the world. The high population density, flammable building materials, and using open flames energy resources instead of electric ones heighten the fire risk. In Delhi, the traffic is a huge problem for the fire services, attending a fire can take a delay between 40 to 45 minutes. Another issue is concerning finding the precise location of the fire, being very difficult due to the absence of formal postal addresses. (Rush, n.d.)

When fire units reach the destination, it may not be able to approach the fire, due to the narrowness of the paths. In these cases, multiple 100 meters hoses are bonded together, reaching distances of 500 meters or more. Also, water resources generate troubles in most areas of Delhi,

since they do not have fire hydrants and if so, they may have low pressure or limited supply. (Rush, n.d.)

As a solution, the fire services of Delhi have attempted to tailor their equipment to better attend informal settlement fires. It includes smaller four-wheeled vehicles equipped with hydraulic pumps or foam devices and motorcycles equipped with four foam-filled cylinders. Regarding water resources, the fire services rely on a fleet of tankers ranging in size between 3,000 liters capacity vehicles for narrower streets to 12,000 liters tankers for larger fires. (Rush, n.d.)

South Africa – Cape Town

Cape Town as other informal settlements in study, they have been similarly data underreported. Contributing to the electrification of the dwellings is viewed typically as a method for improving fire safety, as inhabitants can recede from using open fire stoves. Notwithstanding, even when inhabitants have access to metered electricity, around 67% of them still use these non-electrical energy resources, this mainly due to the higher cost of electricity compared with other energy resources. (Rush, n.d.)

The municipalities have been rolled out smoke and fire detectors. A recent study performed in Wallacedene TRA informal settlement, investigated the roll out of 1,400 photoelectric smoke alarm devices, during a year. The results show the devices successfully reduce the incidence of fatal and damaging fires through early warning. Another intervention done in Cape Town was the application of intumescent paints, which expand upon heating, providing an insulating barrier. The effectiveness of these products may be obstructed by factors such as cost, UV resistance, durability and performance in fire. (Rush, n.d.)

Finally, reblocking has been attempted as an option of remodeling informal settlements, since it looks for organizing the settlement and reaches to create spaces for access to the fire services. This process can be highly controversial, as it involves the relocation of some people's homes. This process is typically managed by NGOs and local social movements as mediators of the municipalities. Though some of this reblocking success other ones are forced to stop, due to local opposition. (Rush, n.d.)

6. Discussion

6.1 Data gathered for La Carpio and Roble Norte

With the data shared by the MIVAH in 2005, it was possible observing the danger under which people live in La Carpio informal settlement. There are several social risk factors surrounding the inhabitants that can affect them and the development of the informal settlement. Also, these data allowed understanding the vulnerability condition under these people live. More recent data regarding these social issues were not obtained, further censuses are needed to draw conclusions and recommendation which help to reach holistic solutions to all the issues existent in La Carpio.

This vulnerability condition due to their social problems joined to the absence of sewage, good electrical connections, house lacking, high likelihood of facing emergencies, among others, make them a high priority zone to attend. A limitation who gets worse this issue is the lack of information regarding features of the community, including sociodemographic, physical, economic, disaster database, and so forth. Having an interrelated database among the public institutions could be an important advance for the entities or researchers who are searching solutions for this community.

Comparing the information collected from La Carpio by different institutions allows determining the magnitude of discrepancies among them. **Table 14** displays a summary of these data collected, making it easier to observe the differences or similitudes. When comparing the information collected by the MSJ against the INEC, there is a great similitude among them. On the other hand, when compares the data reported by the MIVAH and the INEC there are important discrepancies.

Table 14. Comparison from La Carpio sociodemographic information.

Detail/Institution	MIVAH	INEC	MSJ
Area (km2)	0.46	-	0,35
Total Population	39,000	19,035	18,326
Total homes	4,500	4,700	4,571
Average dwellers per home	9	4	4
% People between 0-14 years	-	34.40%	34.80%
% People between 15-64 years	-	63.20%	63.30%
% People with 65 years or more	-	2.40%	1.80%

Source: (MIVAH, INEC, and MSJ.)

Regarding the total population, MIVAH reported 39,000 inhabitants meanwhile INEC reported 19,035 there is a difference of %51.19 in the data reported between the two institutions, being

MIVAH's data around two times the reported by the INEC. According to MIVAH's data, the average of people living in a dwelling is around 9 people per house, while INEC reported just 4 per house. Although there are huge differences between some data, in other cases the information is quite similar, for example, the MIVAH reported a total of 4500 homes while INEC reported 4700 having a difference of %4.26 only.

These discrepancies between government institutions difficult to know certainty the social features of the settlement, and it allows questioning the reliability of the data or the methods used to gather the information. It is difficult to form accurate judgments or draw conclusions that could help to address future solutions for the issues in this settlement. It must be noted, gathering data or keep it updated in this informal settlement is difficult due to the dynamism of the population, which comes and goes randomly, also due to the exponential growth experienced in La Carpio.

Comparing the information regarding education, employment, and house tenancy, **table 15** summarizes the data gathered by the INEC and INCAE. The INCAE data was collected in 2018 while the INEC data is from 2011. In the INCAE report, some data was extracted from the same census carried out by the INEC, even though there are differences among the information reported. One of the assumptions made by the author is the INEC give to the INCAE updated data from the Encuesta Nacional de Hogares (ENAHO, National Household Survey), there is just an assumption, thus this statement cannot be taken as true.

Table 15. Comparison from La Carpio education, employment, and house tenancy information.

Detail/Institution	INEC	INCAE
% Population illiterate	3.60%	8.30%
% Population with cellphone	69.00%	90.30%
% Dwellings in disrepair	23.50%	24.30%
People with own house	9.1	9.1
Unemployment rate	4.4	4.5

Source: (INEC, INCAE.)

As observed, the bigger differences are between the percentage of people illiterate and the people having a cellphone. In both cases, the percentage rose, while in the other elements the information is pretty similar. The increase in the number of people using a cellphone is advantageous, since it can be useful when emergencies happening, and enhancing communication among the neighbors of the community.

In some occasions, as with the MSJ, the information collected does not have the date, being difficult to make comparisons between institutions, since it is unknown how recent the data is. In other cases, the information does not match as MIVAH with the data for the period 2011 – 2013 and INEC which publish their data in 2011. Even when surveys or censuses were done on similar dates, there are important differences between them which put on doubt the reliability of

the information.

All these contradictions and information lacking prevents the advance of the investigations in progress or the start of the ones who want to be performed. This is why it is necessary to establish an interinstitutional database that allows having information constantly updated. Also, if join efforts it could be easier to carry out census or surveys in this community, analyze the data and propose projects which enhance the lifestyle of the people inhabiting this settlement.

When discussing the Roble Norte sector, it must be mentioned the information gathered cannot be compared, since the delimitations and territorial extensions for every institution are different for this sector, and sometimes as in MIVAH's case the delimitation of these sectors are unknown. Due to these different delimitations, the information collected by every institution could vary, because they are taken the data from different locations of the sector, and everyone is reporting this data as the Roble Norte sector. To solve this issue, the nine sectors of La Carpio must be legally delimited, allowing the institutions to collect data over the same land extension.

Concerning the risk matter in La Carpio, it is needed a risk inventory with more detail, which allows detecting the main hazards affecting the zones and how to establish measurements that could help mitigate it. In this detailed risk inventory, for the fire issues, it is necessary to have updated information about the water resources and hydrants surrounding the zone, like conditions, flow rates, and others. Since fires are currently the disaster with more probability of happening in La Carpio, according to the data shared in the previous section, and with the number of emergency calls receive about possible fire causes.

Fires could be the more destructive disaster in La Carpio, since the fire spread is easier due to low-quality construction materials, garbage surrounding the dwellings, wind speed, proximity among the houses, and so forth. Factors that could worsen the situation. The firefighters, regarding the hydrants condition, commented in the interviews that during the day the water flow in this settlement usually is lower than at late-night. This could be related to the fact that all the hydrants and the water for the people in this settlement are linked to the same main pipe.

In La Carpio, as observed in **Table 9** most of the emergency calls received are related to LPG leakages, when consulting the INEC database, it was observed the main fuel use for cooking in this settlement are the LPG gas cuisines. When it comes to gas installations there is the same problem as the electrical connections, they are in bad conditions and most of the time, according to the firefighters, without the safety devices needed.

When a fire occurs in this settlement, the response of the firefighters must be faster, since the fire grow easily. It is difficult for the firefighters to access the zone because in some sectors the alleys are narrow, the floor surfaces are uneven and sometimes holes can be found in the middle of the path, as can be observed in **figure 24**. Joined to the access difficulty, the absence of water resources and other factors boosting the fire spread, the actions done by the population also affect the firefighters' response. The population when it comes to fires, take their possessions

and locate them in the middle of the alleys, obstructing even more the transit, also in some cases other people take advantage of the situation and stole the firefighters' tools, so they need to be aware at the same time of the fire and their fire units.

The involvement of the community in the extinguishing process also affects the attention of the emergency. The people living in this settlement take extinction work into their own hands, risking their lives, and hindering the firefighters' work. What firefighters have chosen to do, is to work with this population, taking advantage of their force and using them for the extinguishing labor.

Regarding La Carpio overall, when the author asked to the Comisión Nacional de Emergencias (CNE, National Emergency Commission), about prevention plans for this settlement, they informed they do not have any prevention plan and addressed the author to the risk management office from the MSJ. Asking this office, they commented they are in constant communication with La Carpio community, but this contact is something novel, thus, plans for emergencies are not performed yet.

Though no safety plans are performed, some efforts for fire safety improvement are being developed by governmental institutions. For instance, the grouped measurement system by the CNFL is helping to avoid fires in La Carpio. In the near future, with Las Gradas new project, the CNFL will help to minimize the constant fire risk in this zone. As observed in the previous section, in this zone there are several connections, most of them in deplorable conditions. This project aims to solve these electrical connections, making it safer for the people inhabiting in here and improving their lifestyles.

6.2 Possible application of international measurements

In the last years, the informal settlement fire issues in Costa Rica have been increasing, hence a temporary solution must be proposed. Knowing about the solutions given by other countries could help to address investigation to find a solution tailored to the Costa Rican problem. This research steers the efforts towards the Roble Norte sector of La Carpio, this zone shares some similarities with other informal settlements around the world, thus some strategies implemented before could be used here. For example, observing the Lebanese case, and how they solve it could be an adequate start for the Roble Norte problem. Training the population about how to prevent, prepare and respond when facing a fire emergency, could help to avoid fire spread and consequently having less human and material losses. An idea that could be applicable is the Fire Department of Costa Rica develop fire workshops for the community members, and search for donations of smoke alarms or other fire devices that could help when responding a fire.

As India's case, the Fire Department of Costa Rica bought motorcycles for fire extinguishing, the only problem with this is they do not have personnel with a suitable drive license, thus this

units cannot be used. Regarding the Cape Town case, the use of intumescent paints could be applicable too, but this entails a cost that cannot be affordable for the house members, thus, it must be deemed try to get donations. Currently what the government is trying to do is relocating them, but the expansion of the informal settlements is faster than the solution. Therefore, a joined effort between the government and the community members must be done to attempt to solve this problem adequate for both parties.

7. Conclusions and Recommendations

7.1 Conclusions

The development of this research allows the author to conclude the following:

1. Costa Rica is currently in a problem-solving early stage. All the institutions at this point, are just trying to understand how to begin addressing the overall issue, in order to find out what is needed to propose a solution for the different problems linked to the informal settlements.

2. Further investigation needs to be done in order to determine if find and apply a solution regarding the fire safety problem is feasible or not.

3. All the sociodemographic features make unique the settlement in study. If any solution to the fire safety issue wants to be exposed, it must be taken into count the physical characteristics of the zone, the features of the population inhabiting, and their culture, since they can affect the response of the population against an emergency.

4. In a fire, the response of the inhabitants could be bonded to their property tenancy. Fighting a fire or taking their stuff and leave the place, are behaviors that could be linked to the property ownership; thus, it will not be the same answer to fight for their own house as for a rented one.

5. The people's actions must be taken in count when developing preparedness, response, and recovery plans. There is needed more research regarding human behavior in informal settlement fires, to discover how the actions done by the inhabitants can interfere in the development of an emergency and how it can be deemed in future safety plans.

6. All the information gather was useful for reasons of settlement description, and to forge an overall insight of the settlement in study. However, none of the data collected is useful at this point to propose new projects or solutions regarding any issue n this zone.

7. When analyzing which data is available, it was identified there are several variables inexistent. Furthermore, the information is antique and inaccurate, thus, there is necessary to carry out a new census to generate a new database. This d updated database will help to give better and most accurate recommendations, to draw specific conclusions and find out solutions fittable to the settlement in study.

NOTE: More investigation is needed to validate several statements mentioned above.

7.2 Recommendations

1. Enhance the communication between government institutions, in order to establish and inter-institutional database that keeps updated. This database must register all the information and statistics collected by the different public institutions, according to the topics they are in charge of. The database may be consulted by all the members in order to facilitate the information flow for project development.

2. Research must be carried out in conjunction with MIVAH, in order to understand why the people move into informal settlements. Aiming to prevent these population to keep moving and try to develop housing solutions for them.

3. In fire cases, establish previously meeting points in the settlement, to ease the counting of those affected by the emergency, and to determine if there are missing people. Furthermore, to have a place where the people can gather when during the emergency, avoiding hindering the firefighters and rescue brigades.

4. To perform an investigation to determine how to mitigate the effects of the weather in fires start.

5. To research if some of the solutions applied by other countries can be functional to the Costa Rican issue. Also, using as a guideline the framework wrote by ARUP at 2018, could be a good start to find a solution for the fire safety in informal settlements issue.

6. To develop research regarding human behavior in this kind of fires, in order to understand the relationship between fire management teams and the population inhabiting these settlements. The objective will be to comprehend how the population interferes in the development of the extinguishing process.

8. Appendixes

Benemérito Cuerpo de Bomberos de Costa Rica

Fecha: _____
Estación: _____

LA ENCUESTA ESTÁ MERAMENTE RELACIONADA AL ASENTAMIENTO INFORMAL LA CARPIO

1. ¿Cuáles son las principales causas que inician los incendios?
2. ¿Cuál es el proceso y la duración entre la detección del incendio y cuando se le informa a la Estación (brigada)? *(¿Cómo se dan cuenta?)*
3. *(Luego de que se les informa)* ¿Cuál es aproximadamente el tiempo de respuesta que les toma atender un incendio en La Carpio?
4. ¿Qué factores influyen en el tiempo que duran apagando un incendio? *(¿manejan algún tiempo por m2 extinguido?)*
5. ¿Cómo extinguen los incendios? *(¿cuáles son los equipos o medios más utilizados para apagar el incendio?)*
6. ¿Qué dificultades enfrentan al extinguir un incendio La Carpio a diferencia de una zona residencial?, *(llegar al sitio, dimensiones de las calles, pocos hidrantes, etc.)*
7. ¿Qué medidas preventivas o recomendaciones se le ofrece a esta población?
8. ¿Sabe algo sobre el proyecto de medición agrupada implementado por la CNFL en la zona?, de ser así, ¿Qué opina sobre el programa?, ¿Ha tenido éxito, ha habido alguna mejora después de la implementación de este?
9. ¿Qué propondrían ustedes para disminuir los incendios en este tipo de asentamientos?
10. ¿Podría comentarme su experiencia con incendios en este tipo de asentamientos?

Appendix 1. Survey used in firefighters' interviews
Source: Prepared by the author.

Ministerio de Vivienda y asentamientos humanos MIVAH

Entrevista con: _____

Contacto: _____

Fecha: _____

1. ¿Cuáles han sido las acciones del MIVAH respecto asentamientos informales del país?
2. ¿Están actualmente desarrollando algún proyecto en la comunidad de La Carpio? de ser así, ¿de qué trata?
3. En este proyecto que están realizando ¿Quiénes son las principales partes involucradas o interesadas?
4. En la jerarquía de riesgos, ¿Cuál desastre opinan ustedes que es el que más afecta el sector de La Carpio?
5. La Carpio es una zona de alta vulnerabilidad ante eventos de incendio, entonces, ¿Cómo podría intervenir el MIVAH en la zona respecto a protección contra incendios?
6. Actualmente, cuando se da un evento de este tipo ¿Cómo intervienen?, ¿qué hacen para ayudar a la población?
7. ¿Cuáles entes consideran que deben tener mayor involucramiento relacionado con el tema de incendios? (Ya sea prevención o resiliencia)
8. ¿Qué acciones consideran ustedes que deben mejorarse al atender casos de incendios en asentamientos informales?
9. ¿Ven ustedes una solución posible para este problema?
10. Para el Ministerio ¿Cuál es el eje prioritario de trabajo en La Carpio?, ¿qué es lo principal que desean solucionar?
11. ¿Cómo creen ustedes que se pueda lograr conocer el verdadero tamaño y características de las viviendas de La Carpio?, ¿Qué instituciones deberían trabajar en conjunto para lograrlo?

Appendix 2. Survey used in MIVAH interview
Source: Prepared by the author.

Llamadas de emergencia 2017

Categoría / Mes	Area de desechos	Automóvil/ motociclet	Basureros/ Contenedore	C.C	Charral	Elementos energizado	Escape LPG	Falsa alarma	Fuego en vivienda	Inundaciones
Enero	2	-	1	4	1	-	4	-	1	-
Febrero	1	-	1	3	2	-	3	-	-	-
Marzo	3	-	-	1	1	-	1	1	-	-
Abril	-	-	-	3	2	1	5	-	3	2
Mayo	1	-	-	5	1	1	2	1	1	-
Junio	-	-	-	6	-	-	3	1	2	-
Julio	-	-	-	6	-	-	3	-	-	-
Agosto	-	-	-	1	-	-	1		-	-
Septiembre	2	1	-	3	-	-	5	-	1	-
Octubre	1	-	-	7	-	-	7	-	-	-
Noviembre	-	-	-	1	-	-	3	2	-	-
Diciembre	2	-	-	1	-	-	4	-	-	-
Total	12	1	2	41	7	2	41	5	8	2

Appendix 3. Fire calls received from La Carpio in 2017
Source: Prepared by the author in Microsoft excel.

Llamadas de emergencia 2018

Categoría / Mes	Area de desechos	Automóvil/ motociclet	Basureros/ Contenedore	Corto circuito	Charral	Elementos energizado	Escape LPG	Falsa alarma	Fuego en vivienda	Persona electrocutad
Enero	1	-	-	1	2	1	5	-	-	-
Febrero	-	-	-	2	5	-	4	-	-	-
Marzo	2	-	1	1	1	-	-	-	-	-
Abril	1	-	-	1	2	-	5	-	1	-
Mayo	2	1	-	3	-	-	9	1	1	-
Junio	2	-	-	6	-	-	5	-	-	1
Julio	-	-	-	2	1	-	7	-	-	-
Agosto	1	-	-	4	-	-	-	-	-	-
Septiembre	-	-	-	12	-	1	3	-	-	-
Octubre	-	-	-	5	-	-	-	1	-	-
Noviembre	-	-	-	1	-	-	4	-	1	-
Diciembre	1	-	-	1	5	1	2	1	1	-
Total	10	1	1	39	16	3	44	3	4	1

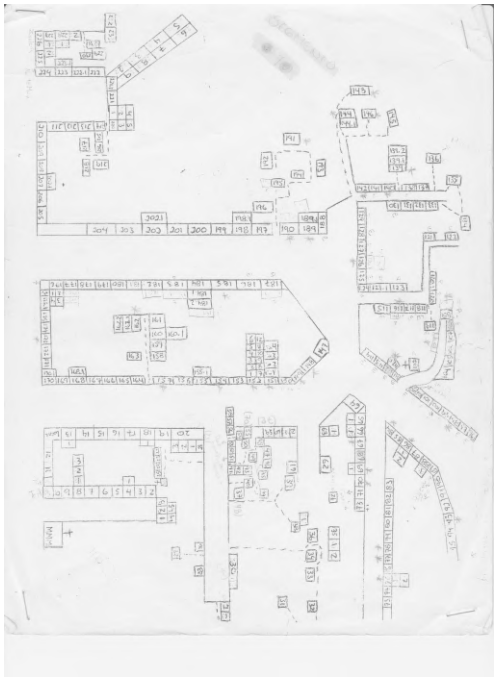
Appendix 4. Fire calls received from La Carpio in 2018
Source: Prepared by the author in Microsoft excel.

Llamadas de emergencia 2019

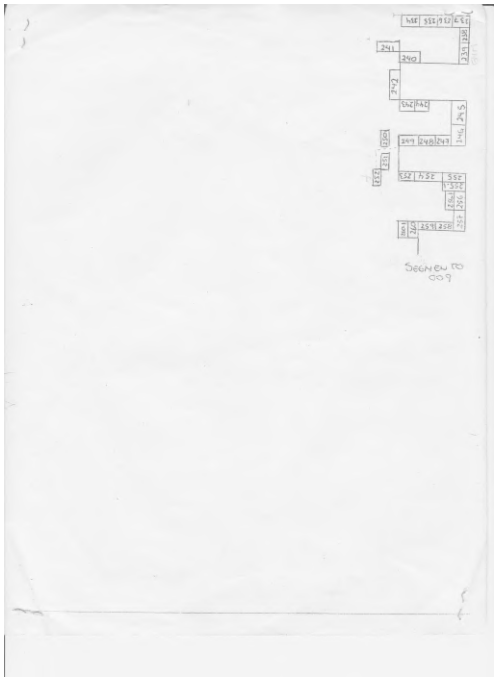
Categoría / Mes	Area de desechos	Automóvil/ motociclet	Basureros/ Contenedore	C.C	Charral	Escape LPG	Falsa alarma	Fuego en comercios	Fuego en vivienda	Persona electrocutad
Enero	3	-	1	-	3	5	-	-	-	-
Febrero	3	-	1	3	9	2	3	1	-	-
Marzo	2	1	-	3	3	3	-	-	2	-
Abril	-	1	-	5	-	3	-	-	1	-
Mayo	-	-	-	-	-	1	-	-	-	-
Junio	1	-	1	4	-	4	-	-	-	1
Julio	-	-	-	1	-	1	-	-	1	1
Agosto	-	-	-	3	-	1	-	-	-	-
Septiembre	1	-	-	3	-	2	-	-	-	1
Octubre	1	-	-	2	-	4	-	-	-	-
Noviembre	-	-	-	3	-	2	-	-	1	-
Diciembre	2	-	-	2	2	2	-	-	-	-
Total	13	2	3	29	17	30	3	1	5	3

Appendix 5. Fire calls received from La Carpio in 2019
Source: Prepared by the author in Microsoft excel.

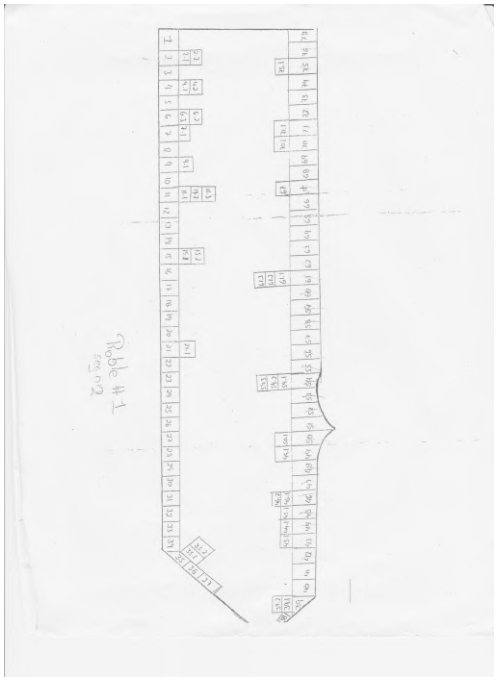
9. Annexes



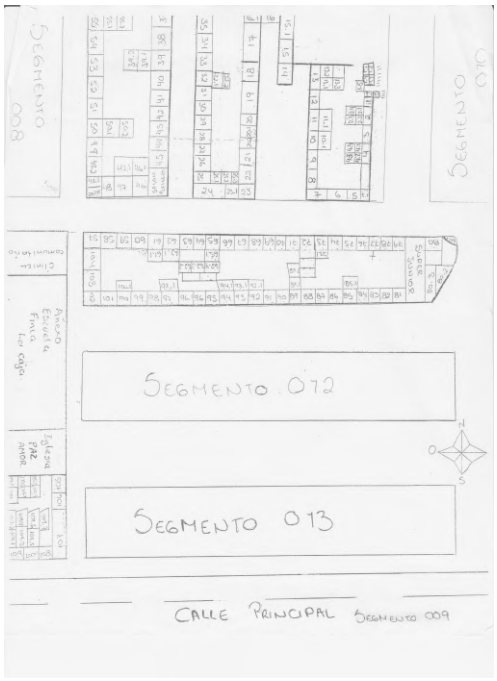
Annex 1. Roble Norte sketch 1
Source: La Carpio health center, 2019.



Annex 2. Roble Norte sketch 2
Source: La Carpio health center, 2019.



Annex 3. Roble Norte sketch 3
Source: La Carpio health center, 2019.



Annex 4. Roble Norte sketch 4
Source: La Carpio health center, 2019.

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