Optimizing Client Scheduling and Improving Client Distribution for Fundación Paraguaya

BY:

Elia Perez Luna

Veronica Soto-Belloso

ADVISORS:

Peter Hansen, Ph.D.

Karla Mendoza-Abarca, Ph.D.

Andrew Trapp, Ph.D.

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Abstract

The goal of our project was to improve the efficiency of Fundación Paraguaya's Microfinance and Poverty Stoplight Programs by implementing Industrial Engineering techniques. First, we addressed inefficient planning of client meetings through an Excel-based scheduling tool that optimally groups geographically similar meetings. Based on our results, the scheduling tool has the potential to reduce 19.92% of the total distance traveled. Second, we developed a tool to analyze the rezoning of offices by evaluating the impact of the corresponding reassignment of client committees to their respective zones. If all reassignments are made, the total distance reduction will exceed 2,400 miles. Our two deliverables will be implemented upon completion of the project.

Acknowledgements

Authorship

The two students listed on the cover of this report contributed equally to its content and revision.

Table of Contents

List of Figures

List of Tables

1. Introduction

A key study on the cross-country differences in the non-profit sector size identified that 4.75% of the global workforce is dedicated to the nonprofit sector. The study focused on 38 countries that represented a varied selection due to the combination of developed and non-developed countries (Pevcin 2012). The nonprofit sector has experienced substantial growth in recent decades due to poor socio-economic conditions and government inefficiencies (Mendoza-Abarca and Anokhin 2013). Nonprofit and humanitarian sectors represent a vast potential for operations research, a method used to help make executive decisions regarding operations in any field by providing quantitative data. Although this field is commonly associated to applications with commercial and industrial sectors, the interest from researchers and practitioners to apply it to nonprofit and humanitarian sectors has risen due to the unique opportunity to address problems "whose solutions would contribute to meet social and global needs" (Maya 2012).

Humanitarian applications of operations research have primarily been focused on disaster relief. Some, however, have used operations research to tackle problems found in the day-to-day operations of non-profit organizations (NPOs). The dissertation work of Pablo Maya, used optimization methods to help two NPOs improve their efficiency, and also developed algorithms that could potentially be used for other humanitarian-related challenges. His research helped assign and route Teacher Assistants for disabled students in Belgium and plan for the delivery of home care services for the Landelijke Thuiszorg organization. As a result, the NPOs realized the impact optimization could have on their operations, as they could increase their service levels and decrease transportation costs (Maya 2012).

Fundación Paraguaya (FP), an NPO based in Paraguay that works towards poverty alleviation, represents an opportunity for an operations research project. FP was founded in 1985 in Asuncion, Paraguay, and currently has 28 offices around the country. The organization has developed five main programs: a microfinance program, an entrepreneurial and financial educational program for children and youth, self-sustainable agricultural high-schools, the Poverty Stoplight, and TeachAManToFish (Fundación Paraguaya, n.d.-a). The microfinance program started because leaders of FP learned from Mohamad Yunus' microfinance institution (MFI) the impact relatively small loans could have in incentivizing business growth and alleviating poverty (Fundación Paraguaya, n.d.-b). Currently, FP provides financial services to approximately 60,000 low income individuals through their microfinance program (Cite Omar).

FP aims to "strengthen the microfinance program and increase the total number of client committees by at least 2.5 times before 2017" (Fundación Paraguaya, n.d.-a). In order to achieve this goal, FP needs to overcome identified challenges in their day-to-day operations such as lack of organization from their microfinance officers (asesores) and zoning inefficiency of their offices and

workers (Fundación Paraguaya, 2015). These challenges were found through research conducted by FP human resources trainers and confirmed during our interviews in our trip to Paraguay early January 2016. During our trip, we were able to assess those challenges, brainstorm potential solutions, and verify if the solutions would work for FP. Fundación Paraguaya is actively looking for new and innovative approaches to solve their challenges. FP's research confirms the need for flexible tools that help them address their challenges without disrupting the culture and working style of the organization.

Our project intends to assist FP accomplish their goals and overcome their challenges through industrial engineering methods. We intend to aid Fundación Paraguaya in improving the efficiency of its Microfinance and Poverty Stoplight programs. In order to achieve this goal, our team set the following related objectives:

1. Understand the operations of the microfinance and Poverty Stoplight programs to identify challenges and areas of improvement.
2. Evaluate the challenges to design potential solutions that apply Industrial Engineering techniques.
3. Develop two solutions that improve the efficiency of the programs and make implementation plans.

In continuation of this report, Chapter 2 presents background research that includes the context of our project. Chapter 3 discusses the methods used to achieve our objectives and describes our two main deliverables. Chapter 4 presents the results and analysis of our methods. Finally, Chapter 5 describes our conclusions, impact of our deliverables, and future recommendations.

2. Background

2.1 Introduction to Paraguay

Paraguay is a landlocked country located in Central South America. The Paraguay River flows through the country and divides it into two different areas: the forest on the east and the plains on the west (National Geographic 2005). The population in Paraguay is approximately 7 million, of which 2.5 million live in the capital, Asunción. The official languages are Spanish and Guaraní (Central Intelligence Agency 2013). Many countries in Central and South America were colonized by Spain such as Venezuela, Mexico, Ecuador, and Paraguay. Paraguay, however, has a very different history from the others. The nation did not experience the slavery system that Spain implemented in other countries, such as Mexico and Peru, because it lacked precious ores such as gold or silver. Therefore, this characteristic was a blessing for the nation as the colonization process was more humane in Paraguay than in any other nation in South and Central America (Hanratty and Meditz 1988).

After three-hundred years of Spanish rule, along with frequent conflicts with Argentina, Bolivia, and Brazil, and unstable governments, most people in Paraguay were uneducated, unaware of the world, and lacked experience of a democratic environment (Hanratty and Meditz 1988). These times of instability delayed development in Paraguay. Moreover, between 1998 and 2002, the country went through a deep economic recession and poverty rates rose from 32% to 41%. Due to deficiencies in the government's planning, poverty alleviation programs had not been successful. These attempts had focused solely on telecommunications, livestock and mechanized farming instead of poor communities (Steele, Fernando, and Weddikkara 2008).

According to the market failure perspective, it is common for NPOs to emerge with the purpose of addressing social issues that current governments and markets have not been successful in targeting. Poor socioeconomic conditions and government inefficiency produce an increase in the creation of NPOs (Mendoza-Abarca and Anokhin 2013). Similarly, NPOs in Paraguay have taken on the task to try to alleviate poverty in the nation with effective programs without governmental barriers such as bureaucracy and corruption.

2.2 Overview of our Sponsor, Fundación Paraguaya

Fundación Paraguaya (FP) is an NPO that has worked towards poverty alleviation since 1985. Martin Burt, FP's founder and CEO, has served in various governmental roles, such as Mayor of Asunción, Vice Minister of Commerce, and Chief of Staff to the President of Paraguay (Fundación Paraguaya, n.d.-a). Burt founded FP in 1985 envisioning Paraguay to become "entrepreneurial and poverty-free, an example to the world" (Fundación Paraguaya, n.d.-a). FP's mission is to develop and

implement practical, innovative, and sustainable solutions to eliminate poverty and create decent living conditions for every family (Fundación Paraguaya, n.d.-a).

FP has 28 offices and staffs 450 employees around the country. The organization has focused on five main programs: a microfinance program, an entrepreneurial and financial educational program for children and youth, self-sustainable agricultural high-schools, the Poverty Stoplight, and TeachAManToFish. The organization started working in microfinance in 1985 when Martin and other leaders of FP learned that access to a relatively small loan given to a low-income individual could make a difference and incentivize business growth and poverty alleviation (Fundación Paraguaya, n.d.-a).

FP's main goals to accomplish by the end of 2017 to "strengthen the microfinance program and increase the total number of client committees served by at least 2.5 times". One of their main objectives is to optimize the use of resources in order to increase efficiency of the work conducted. In this manner, they can reach the greatest possible number of people represented in their target population. In addition, FP considers themselves an innovative organization that seeks to apply updated methodologies and technologies to solve worldwide issues (Fundación Paraguaya, n.d.-a). Our project intends to assist FP accomplish this objective by implementing technologies to improve the organization and effectiveness of the asesores in the microfinance program.

2.3 Microfinance

Nearly three billion people have little or no access to financial services (Murray 2010). Microfinance loans are a solution for low-income individuals and communities that find themselves excluded from banking, savings, and credit arrangements (Castree, Kitchin, and Rogers 2013). It is a commonly used approach to alleviate poverty as it offers small loans with no collateral requirement to the poor in both developing and developed countries (Sengupta and Aubuchon, Craig 2008). This service helps poor individuals become entrepreneurs, have a better nutrition, improve their living condition, and provide health benefits and education for their children.

2.3.1 History of microfinance

Microfinance dates back to the 18th century where it was used as a strategy to alleviate poverty. During the 1720s, the Irish Loan Funds emerged, and provided small loans with peer mentoring to enforce the weekly repayments. This is considered an early version of what microfinance is today (Hans Dieter 2003). In 1974, Dr. Mohammad Yunus, a professor from Bangladesh, pioneered modern day microfinance during an action research project near Chittatong University in Bangladesh. The research aimed to test that if the poor were provided with working capital, they could become self-employed without depending on external assistance. Yunus found women in Jabra, a small village in Bangladesh, who were selling their products and making a profit of two cents. The women, who had no money to buy raw materials, borrowed from middlemen, who gave them money with the condition of selling the

finished product back to them at a price they specified. Yunus realized that if there was a system that lent individuals small loans to sell their products at the price they wanted, the individuals could make more profit. As a result, he began to loan small amounts of money (about $27) to 42 women that sold their own products. He realized small loans could motivate borrowers to get themselves out of poverty. In 1983, his project evolved into the Grameen Bank, a formal and independent financial institution. The Grameen Bank objectives were to eliminate the exploitation by money lenders, and create opportunities for self-employment in an area where manpower resources were under-utilized (Alam and Getubig 2010). Since then, microfinance has spread to five continents, and commercial microfinance programs began to emerge.

2.3.2 The Microfinance System

A typical microfinance system includes three main stakeholders: Microfinance Institutions (MFIs), loan officers, and client committees. MFIs can be NGOs, savings and loan cooperatives, credit unions, government banks, commercial banks, or nonbank financial institutions (Ledgerwood 2014). Loan officers usually serve as the liaison between the MFI and its client committees. They promote the microfinance program, identify possible client committees, stay in touch with their client committees, and ensure their client committees repay their loans on time (Siwale and Ritchie 2012). Client committees are usually self-employed, low-income entrepreneurs in both urban and rural settings. Most MFIs provide credit either through group lending or through individual-based lending. The majority of microfinance borrowers participate in the group lending program (Ledgerwood 2014). In the group lending process that Grameen Bank developed, borrowers form a group, agree to get a small group loan, and repay their loan weekly. Each individual chooses the loan size he or she will be responsible for paying each week. If any member of the group misses a payment, all members are denied future credit. This incentivizes group members to monitor other members and enforce repayment to ensure getting future loans. On the other hand, individual-based lending is similar to traditional banking and includes a direct relationship between the program's loan officer and the borrower (Hermes and Lensink 2007).

2.3.3 Microfinance Program in Fundación Paraguaya

Through its microfinance program, Fundación Paraguaya (FP) aims to promote the development of microenterprises and low-income individuals by providing financial services and regular follow-ups and workshops. Their main products include microenterprise credits, women committee credits, agricultural credits, and individual credits. In 2013, FP worked with approximately 57,000 families in Paraguay and was able to help over 6,000 families get out of poverty. Since August 2015, FP's officers also administer the Poverty Stoplight along with the microfinance program. Poverty Stoplight is one of FP's social programs that allows client committees to self-assess their level of poverty and develop a plan to overcome it (Fundación Paraguaya, n.d.-b)

5

For the purposes of this project, our team intends to analyze the operations of the group lending microcredit program, which specifically targets female client committees. This branch of FP accounts for 24 offices and around 86,000 client committees. Each committee in the program is composed of 15 to 20 women. FP administration intends to improve efficiency within the program as it faces a series of challenges. First, the loan officers, known as asesores, are responsible for numerous monthly tasks and feel overwhelmed. These tasks include promotion of the program to get new client committees, the establishment of new committees that require four initial meetings, monthly visits to each committee, monthly visits to poverty stoplight client committees (around 35 visits), unpredictable visits to client committees who are late in their payments, and administrative work. Each visit can take an asesor up to four hours because of the time of transport (Amarilla 2016). Second, presently the offices do not geographically limit the space where their asesores can get their client committees. This results in asesores traveling greater distances to acquire new client committees as well as visit existing ones. Third, due to the bonds of trust between client committees and asesores, many asesores are not willing to swap client committees with other offices to reduce the distance they have to travel (Sanabria 2016).

2.4 Challenges Faced by Fundación Paraguaya

In this section, we summarize the findings of research conducted by human resources trainers for FP's Poverty Stoplight program. This research, along with the information obtained in interviews, allowed us to narrow down the scope of our project to two challenges. These include the lack of planning by asesores and the zoning inefficiency of the organization.

2.4.1 Research Conducted Concerning Challenges of Fundación Paraguaya's Administration

Research conducted by FP's Poverty Stoplight training team analyzed the day-to-day activities of asesores to determine the most efficient way to increase productivity and implement the Poverty Stoplight with more commitment. It was conducted during October 2015 and sampled 10 national offices and 31 asesores, which represents 42% of all the offices in Paraguay. The research was conducted because asesores showed discontent towards their high amount of work responsibilities, which threatens to affect the quality of the job they conduct (Fundación Paraguaya, 2015).

One key finding of this research is the contrast between the expected travel time and the real travel time of the asesores, as well as the contrast in times of transport in rural areas versus urban areas. In one instance, in an urban office, a client was located 38 kilometers away from the office and according to Google Maps, it would take around 49 minutes in bus. In actuality, it took the asesor 1.3 hours for one trip. On the other hand, in a rural office, a client was located 59 kilometers away from the office and according to Google Maps, it would take around 1 hour and 13 minutes. In actuality, it took the asesor 3 hours for one trip via motorbike. From this information, it was concluded that the distance to be traveled

had great potential to be improved. The team collected the major complaints made by asesores which were travel time, lack of safety, relationship with other asesores, and work hours. The main causes identified for these complaints were lack of organization, inefficient use of time, on-the-job pressure due to numerous activities to be completed, and tardiness of the client committees for meetings. The research suggests the implementation of asesores in the Poverty Stoplight best practices and to organize the activities of the asesores including planning the meetings ahead of time (Fundación Paraguaya, 2015).

2.4.2 Individual Challenge: Lack of Planning by Asesores

One of the main challenges FP faces is the lack of organization of each asesor. The asesores report to be overloaded with work and are unhappy with the current way they are performing in their jobs. There is high pressure on the asesores because their commission depends on the amount of client committees they have. They are also required to visit Poverty Stoplight client committees even though they do not receive commission for those visits. Another challenge is the transportation cost, as asesores get reimbursed for transportation only up to a certain fixed amount of money. Moreover, asesores currently travel to visit client committees based on their availability. Therefore, sometimes they go to opposite sides of the city for visits on the same day (Sanabria 2016). Another factor is asesores usually schedule visits the day before, rather than further in advance. (Amarilla 2016). In consequence of the late planning, the asesores do not organize their schedule efficiently.

2.4.3 Organizational Challenge: Zoning Inefficiency

Zoning represents a main challenge for FP in its Microfinance Program. Omar Sanabria, the Microfinance Program manager for FP, stated during an interview that "limits were never set for the offices" (Sanabria 2016). As a result, there are client committees that are closer to an office x but are registered in office y. Consequently, within the same office, different asesores visit the same areas instead of having each asesor cover a specific area. This can lead to higher transportation costs and other tasks with non-value added time (Sanabria 2016).

The research and the information obtained from FP workers supports the need for a tool that can improve the efficiency of the asesores using industrial engineering methods such as optimization.

2.5 Optimization

Optimization intends to model a real-world problem and find the best solution to all possible alternatives and proving that the one selected is the best. Optimization seeks to maximize or minimize a mathematical function of variables, known as an objective function, subject to certain constraints, together with problem specific data. The variables, objective function, and constraints constitute a model, which is a mathematical representation of a real-world problem that aids to solve the problem computationally.

There are a variety of reasons to model real-world problems using optimization, one of them being the decision on how to best allocate limited resources. (Sarker and Newton 2007).
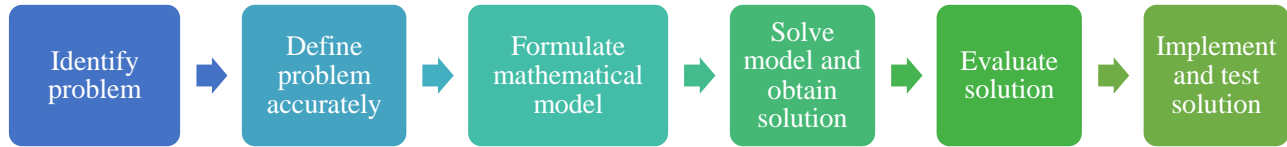
Figure 1: The Decision Making Process adapted from (Newton, 2007)

The use of optimization involves a decision-making process similar to the one shown in Figure 1. The most important and possibly difficult step is to accurately define the real problem. One must include problem assumptions, resources and parameters involved in the problem, stakeholder interests, decision variables, an objective, constraints, and the measure of effectiveness to compare alternatives. Once an optimal solution to the model is obtained, the solution remains to be interpreted and evaluated. This requires the conversion of mathematical findings into easily understood procedures, which helps decision makers introduce the changes required to reach the desired outcome. The implementation of a solution requires a frequent monitoring and re-evaluation of the performance (Sarker and Newton 2007).

Optimization has been successfully applied to a wide variety of real-world problems. In business, optimization helps companies consider complex transportation cost structures, warehouse sizes, manufacturing limitations, inventory costs, and service levels. Similar problems also exist in humanitarian organizations; therefore, they can likewise benefit from optimization-based decision making. A thesis done by Pablo Maya explores the "use of operations research models and methods to solve problems in the non-profit and humanitarian domains" (Maya 2013). He used optimization in two cases. The first one was the assignment and routing of Teacher Assistants of an Institute in Belgium that provides assistance to disabled students. The second helped the organization Landelijke Thuiszorg to plan the delivery of their home care services. The results of his research helped both organizations realize that by optimizing their operations they could increase their service level and decrease transportation costs. The savings could then potentially be used to enlarge the group of beneficiaries or invest in new programs (Maya 2013).

To address the identified challenges of FP, our team will focus on two main types of optimization problems, the Clustering problem and the Set Partitioning Problem.

2.5.1. Clustering

The clustering problem partitions a set of data points into a set of subgroups or clusters which are as similar as possible. Clustering models generally seek to form clusters that are mutually exclusive and exhaustive. As a result, data points assigned to the same cluster are more similar to each other than they are with data points in a different cluster. Clustering is commonly used in numerous applications, including data mining, collaborative filtering, customer segmentation, data summarization, dynamic trend detection, data analysis, and social network analysis (Aggarwal and Reddy 2013). Optimality of a clustering problem depends on the application it is used for such as the creation of clusters by proximity (Rao 1971). "Every clustering algorithm is based on an index of similarity or dissimilarity between data points" (Aggarwal & Reddy, 2013, p. 6). In a clustering problem, similarity measures, dissimilarity measures, or distances are used to quantify the similarity or dissimilarity of two data points. When using similarity measures, the greater the similarity coefficient, the more similar the two data points are. When using distance, a greater distance represents dissimilarity between two data points (Gan, Ma, and Wu 2007). The number of clusters in a clustering problem is typically predetermined (Gan, Ma, and Wu 2007).

An incremental approach to the clustering problem is the global k-means algorithm. The k-means algorithm consists on adding one cluster center for each cluster (Likas, Vlassis, and Verbeek 2003). The algorithm's objective function is based on the clustering error criterion. The clustering error criterion calculates the square distance from each cluster center to each data point and then sums the distances for all points (Likas, Vlassis, and Verbeek 2003). The algorithm places cluster centers arbitrarily and proceeds to move the centers until the clustering error is at its minimum value (Likas, Vlassis, and Verbeek 2003).

Clustering is a potential solution to the organizational problem of the asesores. It can be used to group different meetings according to their geographical location and propose a schedule to asesores. We consider it in our methodology.

3. Methodology

This project intends to use Industrial Engineering methods to aid Fundación Paraguaya in improving the efficiency of its Microfinance and Poverty Stoplight programs through the completion of the objectives mentioned in Figure 2.
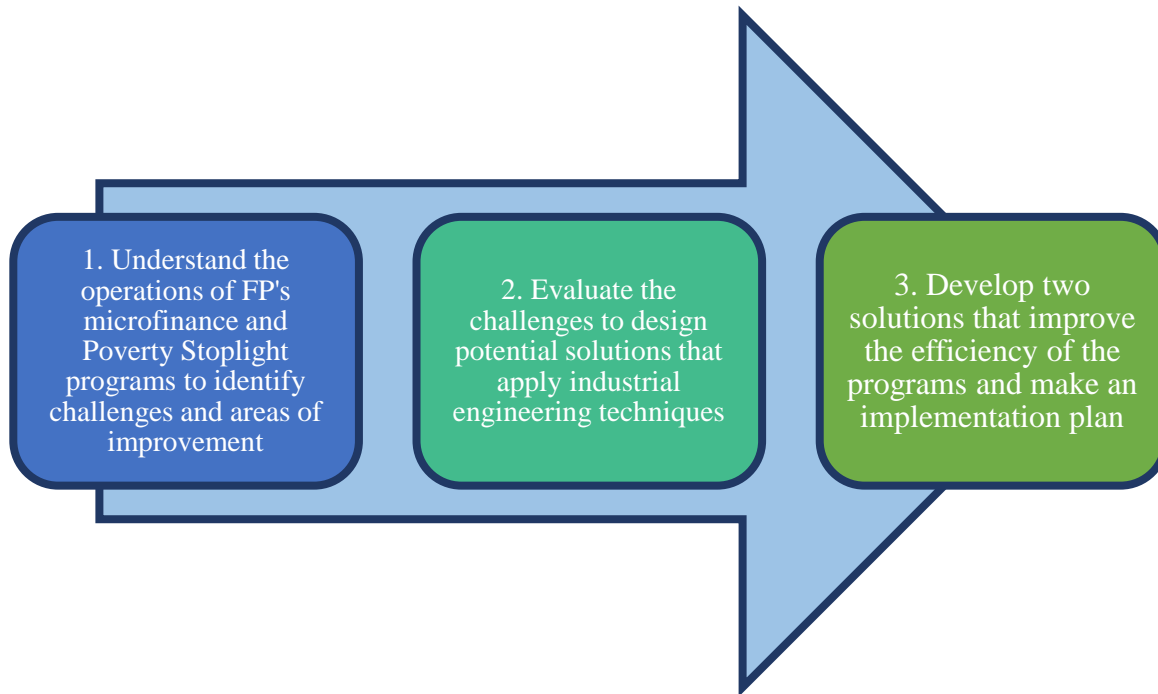
Figure 2: Project Objectives

This chapter discusses the methods carried out to achieve the determined objectives.

3.1 Understand the Operations of Fundación Paraguaya's Microfinance and Poverty Stoplight Programs and Identify Challenges and Areas of Improvement

To achieve our first objective and gain a better understanding of FP's microfinance program operations, our team traveled to Asunción, Paraguay in early January 2016. We obtained qualitative data by visiting different microfinance offices, interviewing the major stakeholders, and identifying areas for improvement with managers, asesores, and administrative staff members.

3.1.1 Visit to Fundación Paraguaya

Prior to our visit, we communicated with Martin Burt through Skype and met with him personally when he came to WPI to discuss possibilities of developing a project with FP. During one of those meetings, we determined the need to physically go to Paraguay to collect more information and understand the problem as much as possible. Martin mentioned there were challenges with the asesores of the microfinance program in terms of their efficiency. We immediately started thinking of possible

solutions using Industrial Engineering techniques. One key factor we all understood was that the problem we were addressing was not solely numerical as we had to consider human and social dimensions.

During our visit, our team went to three offices within one week. We visited the main office (HQ), an office in an urban area, and an office in a rural area. Through those visits, we were able to get a better understanding of the program's operations, understand the differences between the work environment in an urban setting and the work environment in a rural setting, and understand the challenges FP workers face every day. We documented our findings from each visit and gave a presentation to FP administration.

3.1.2 Interviews

In each of our visits, we interviewed some of the major stakeholders of the microfinance program: FP administration, the general manager, office managers, HR trainers, and asesores.

First, we met with administrative staff members to get the overall idea of the program's operations. The main objectives of this initial meeting were to meet FP's administration, to learn about the program's activities, and to establish initial goals for our stay in Paraguay and for the project. We performed conversational interviews with six administrative staff members. We documented the general processes of the program, identified challenges based on their perspective, and identified potential limitations for any change made to the program. Second, we interviewed the general manager of the microfinance program. The main objectives of this interview were to understand specific processes within the program, understand the worker incentive scheme, understand the impact of inefficiency on FP, and verify if some potential solutions could work for the organization.

Third, our team visited two offices: one in an urban setting and another in a rural setting. We met with the manager of each office to understand their role in the office, identify the challenges they face, define their day to day activities, and understand how they set goals for each office and for their workers. Fourth, we met with an HR trainer for the Poverty Stoplight program. Because asesores have to carry out Poverty Stoplight activities, this interview served to understand the details of the combination of the processes in both the microfinance program and Poverty Stoplight program, and to identify the challenges associated with combining this problem.

Finally, we met with asesores to identify all the activities they perform including meetings, calls, and administrative work. We identified the challenges they face, understood the organization of the asesores and the scheduling process of meetings, and defined the resources they use to perform their duties. All of our interviews were informal, conversational, and conducted in Spanish. These interviews shaped our goals and objectives and redefined the initial conception of the project.

3.1.3 Shadowing an Asesor

Our team shadowed one asesora in an office located in Villa Elisa, an urban district near Asunción. Through this, we observed some of the usual tasks an asesor performs, recorded the time of transportation to the meeting, and witnessed a women committee meeting.

3.2 Evaluate the Challenges and Design Potential Solutions that Apply Industrial Engineering Techniques

To achieve our second objective, our team determined challenges to address, evaluated potential project options, determined feasibility of initial solutions, and presented findings and potential solutions.

Before arriving in Asunción, our team analyzed potential project options presented by Martin Burt during a visit to WPI. Two of the ideas were determining the best route for an asesor once he knows which client committees he or she will visit that day, and allocating resources in Asunción based on Poverty Stoplight data.

While in Asunción, we were able to find out which solutions were feasible for our sponsor and their employees by gathering input through interviews. Being there for a week enabled us to think of potential solutions that could be implemented and tailored to the microfinance program's challenges. As it turned out, most of our initial thoughts would not have worked for FP because we had not considered many factors such as public transportation challenges, and the challenges of scheduling meetings. We were not aware of the combination of the Microfinance and the Poverty Stoplight Program, the relationship of trust between client committees and asesores, or the reluctance of asesores to change their working style.

By the end of our stay in Paraguay, we presented our findings to the administration. We included an analysis of the current state of the microfinance program, a list of all the work-related activities asesores do, the identified areas of improvement, and two potential deliverables that will address the identified challenges. After presenting, we were able to confirm all the information we gathered was accurate and consistent. We also obtained feedback from the FP administration.

After departing Paraguay, we thoroughly analyzed all the data we collected in our interviews, shadowing, and the reports given to us. One particular report was a research and analysis conducted on the asesores' job (Fundacion Paraguaya, 2015). This confirmed that asesores often do not plan their meetings in advance, causing them to sometimes visit the same areas in different days instead of visiting the same areas on the same days. This adds to the work-related pressure of achieving all the job

responsibilities. After reading this report, we confirmed the need for a tool to help the scheduling processes of asesores.

3.3 Develop Two Solutions that Improve the Efficiency of the Microfinance Program and the Poverty Stoplight Program and Make an Implementation Plan

After we evaluated the challenges and weighed potential solutions, our team worked to develop the tools that were going to improve the efficiency of the microfinance program. The team focused on addressing challenges found on the individual level and also on the organizational level, therefore providing two different solutions: one tool that optimizes asesores' scheduling process, and one that analyzes the impact of redistributing the microfinance program's client committees. We divided our time for these tools in two terms of seven weeks each and worked on each project separately. During our final presentation in Paraguay, the administration gave priority to improving the process of scheduling meetings. For this reason, we dedicated our first seven weeks to develop the scheduling tool, and the second seven weeks to analyze the impact of the redistribution of client committees.

Following the completion of the technical aspects of the project, our team focused on making the deliverables user friendly. After visiting Paraguay, we decided that our solutions had to be as simple as possible. To design a user-friendly platforms, we communicated regularly with managers and asesores in Paraguay via Skype to get their feedback.

3.3.1 Optimization of Scheduling Process

Through interviews conducted in January 2016 with asesores, our team identified the process of scheduling meetings as an area of improvement on the individual level of the microfinance program. As a result, our goal was to create a tool that could cluster selected meetings based on geographical location, providing the asesor a proposed daily or weekly schedule. This tool is computational and involves a spreadsheet and a Visual Basic for Applications (VBA) code. The purpose of this development was to improve the scheduling process for asesores by decreasing the time it takes for them to organize themselves. The tool proposes different groups of selected client committees that are in close proximity to suggest asesores to schedule meetings in that manner.

Before leaving Paraguay, we requested monthly asesores' schedules, which were in an Open Office spreadsheet, as well as manuals that explained the details of the microfinance program. After coming back, we analyzed the data we collected to better understand all of the tasks for which an asesor is responsible. Subsequently, we determined the activities we were going to include in the scheduling tool. We focused on activities that implied visits such as conducting the Poverty Stoplight, starting a new committee, visiting committees that have late payments, and visiting a client to renew a credit.

Through research and collaboration with our advisor Professor Andrew Trapp, we identified that a clustering model would be the appropriate option for our type of problem. Once the right model was identified, we started determining variables, setting constraints, and identifying the objective function. Following this step, the team worked on a small exemplary clustering problem with x and y coordinates. After working on a smaller problem set, the team developed a general algebraic model that can be found below. The model takes as input a data set that contains client names and coordinates and allocates them to different clusters based on proximity. In relation to our specific project, each cluster represents a day in an asesor's working schedule.

The formulation of our algebraic model is below.

Algebraic Model Formulation

Sets

C Set of client committees, indexed by c $(c = 1, \dots |C|)$

K Set of Clusters indexed by k $(k = 1, \dots |K|)$

Parameters

ℓ^c Fixed latitude of client c

n^c Fixed longitude of client c

t^c Time of meeting for client (duration)

e_k^c Euclidean distance between client c and cluster k

b Maximum number of meetings per cluster

f Minimum number of meetings per cluster

u Maximum amount of time per cluster

Variables

ℓ_k Latitude of centroid for cluster k

n_k Longitude of centroid for cluster k

z_k^c $\begin{cases} 1, & \text{If client c is assigned to cluster k} \\ 0, & \text{otherwise} \end{cases}$

Model Formulation

Minimize	$\sum_{c=1}^{C}\sum_{k=1}^{K} e_k^c * z_k^c$		(1.1)
Subject to	$\sum_{k=1}^{K} z_k^c = 1$	$\forall c \in C$	(1.2)
	$f \leq \sum_{c=1}^{C} z_k^c \leq b$	$\forall k \in K$	(1.3)
	$\sum_{c=1}^{C} t^c * z_k^c \leq u$	$\forall k \in K$	(1.4)
	$z_k^c \in \{0,1\}$	$\forall k \in K, \forall c \in C$	(1.5)
	ℓ_k, n_k Unrestricted in sign	$\forall k \in K$	(1.6)

The objective function (1.1) minimizes the total distance between client committees and clusters. e_k^c is calculated using the Euclidean distance formula $\sqrt{(\ell^c - \ell_k)^2 + (n^c - n_k)^2}$. In this formula, l_k and n_k are variables. Constraint (1.2) ensures that every client gets assigned to exactly one cluster. Constraint (1.3) imposes that at least f client committees are assigned to every cluster and that the number of client committees assigned to a cluster cannot exceed b. Constraint (1.4) imposes that the total time per cluster does not exceed u.

During the implementation, we encountered one main problem. While the model (1.1)-(1.6) was mathematically correct, it was nonlinear due to two main aspects. First, the formula used to calculate the objective function contained products of variables. Second, the distance was calculated using the Euclidean distance formula that contains squares and a square root, which are not linear. Nonlinearity restricted the model from achieving a global optimal solution. Professor Trapp assisted the team by providing an alternative approach that would accomplish the same outcomes in a linear way. For more details on the modifications made to the model to make it linear see Appendix A.

The final algebraic model after the modifications is found below.

Sets

C Set of Client committees, indexed c ($c = 1, \dots |C|$)

K Set of Clusters indexed k ($k = 1, \dots |K|$)

Parameters

ℓ^c Fixed latitude of client c

n^c Fixed longitude of client c

t^c	Time of meeting for client c (duration)
b	Maximum number of meetings per cluster
f	Minimum number of meetings per cluster
u	Maximum amount of time per cluster
r	Maximum latitude value within the latitude data set
s	Minimum latitude value within the latitude data set
v	Maximum longitude value within the longitude data set
w	Minimum longitude value within the longitude data set
M^c	Large number that uses $r, s, v,$ and w to represent furthest possible distance from any client to any cluster. (See example and explanation below)

Variables

ℓ_k	Latitude of cluster k
n_k	Longitude of cluster k
z_k^c	$\begin{cases} 1, & \text{If client } c \text{ is assigned to cluster } k \\ 0, & \text{Otherwise} \end{cases}$
d_k^c	Distance between cluster k and client c if client c was assigned to cluster k
$\{x_k^{c+}, x_k^{c-}\}$	Nonnegative variables that carry balance of absolute value terms from Manhattan distance
$\{y_k^{c+}, y_k^{c-}\}$	Nonnegative variables that carry balance of absolute value terms from Manhattan distance

Model Formulation

Minimize
$$\sum_{c=1}^{C} \sum_{k=1}^{K} d_k^c \tag{2.1}$$

Subject to
$$\sum_{k=1}^{K} z_k^c = 1 \qquad\qquad \forall\, c \in C \quad (2.2)$$

$$f \leq \sum_{c=1}^{C} z_k^c \leq b \qquad\qquad \forall\, k \in K \quad (2.3)$$

$$\sum_{c=1}^{C} t^c * z_k^c \leq u \qquad\qquad \forall\, k \in K \quad (2.4)$$

$$\ell^c - \ell_k = x_k^{c+} - x_k^{c-} \qquad\qquad \forall\, k \in K, \forall\, c \in C \quad (2.5)$$

$$n^c - n_k = y_k^{c+} - y_k^{c-} \qquad\qquad \forall\, k \in K, \forall\, c \in C \quad (2.6)$$

$$d_k^c \geq (x_k^{c+} + x_k^{c-} + y_k^{c+} + y_k^{c-}) - M_c * (1 - z_k^c) \qquad \forall\, k \in K, \forall\, c \in C \quad (2.7)$$

$$s \leq \ell_k \leq r \qquad\qquad\qquad \forall\, k \in K \quad (2.8)$$

$$w \leq n_k \leq v \qquad\qquad\qquad \forall\, k \in K \quad (2.9)$$

$$z_k^c \in \{0,1\} \qquad\qquad \forall\, k \in K, \forall\, c \in C \quad (2.10)$$

$$x_k^{c+}, x_k^{c-}, y_k^{c+}, y_k^{c-}, d_k^c \geq 0 \qquad\qquad \forall\, k \in K, \forall\, c \in C \quad (2.11)$$

$$\ell_k, n_k \textbf{\textit{ Unrestricted in sign}} \qquad\qquad \forall\, k \in K \quad (2.12)$$

The objective function (2.1) minimizes the total distance between client committees and clusters. Constraint (2.2) ensures that every client gets assigned to exactly one cluster. Constraint (2.3) ensures that at least f client committees be assigned to every cluster and that the number of client committees assigned to a cluster cannot exceed b. Constraint (2.4) imposes that the total meeting time per cluster does not exceed u. Constraints (2.5) and (2.6) ensure that the distance between clusters and client committees' latitudes and longitudes is the same as the difference of the variables x_k^{c+}, x_k^{c-} and y_k^{c+}, y_k^{c-}, respectively, and therefore maintain the Manhattan distance in a linear fashion. Constraint (2.7) imposes that d_k^c needs to be larger than the distance between clusters and client committees assigned to those clusters. Constraints (2.8) and (2.9) impose that the coordinates for each cluster center are larger than the minimum and maximum coordinates of latitudes and longitudes respectively. Constraint (2.11) ensures that $x_k^{c+}, x_k^{c-}, y_k^{c+}, y_k^{c-}, d_k^c$ are nonnegative values.

Example for M^c

Figure 3 shows the functionality of M^c. It depicts 5 client locations according to their (x, y) coordinates. The M^c parameter constrains the model to apply boundaries when searching for the latitudes and longitudes of each cluster center in the following way: $M^c = \max(|\ell^c - s|, |n^c - r|) + \max(|\ell^c - w|, |n^c - v|)$. These boundaries are reasonable because a cluster center would never be placed outside of these minimum and maximum values. In the example below, one can observe the boundaries this formula creates for the centroid location of each cluster. The lower left shaded corner is (s, w) and the upper right shaded corner is (r, v). This allows the solver to find an optimal solution faster.

	x	y
	2	-2
	-5	4
	5	7
	-3	10
	8	-8
min	-5	-8
max	8	10
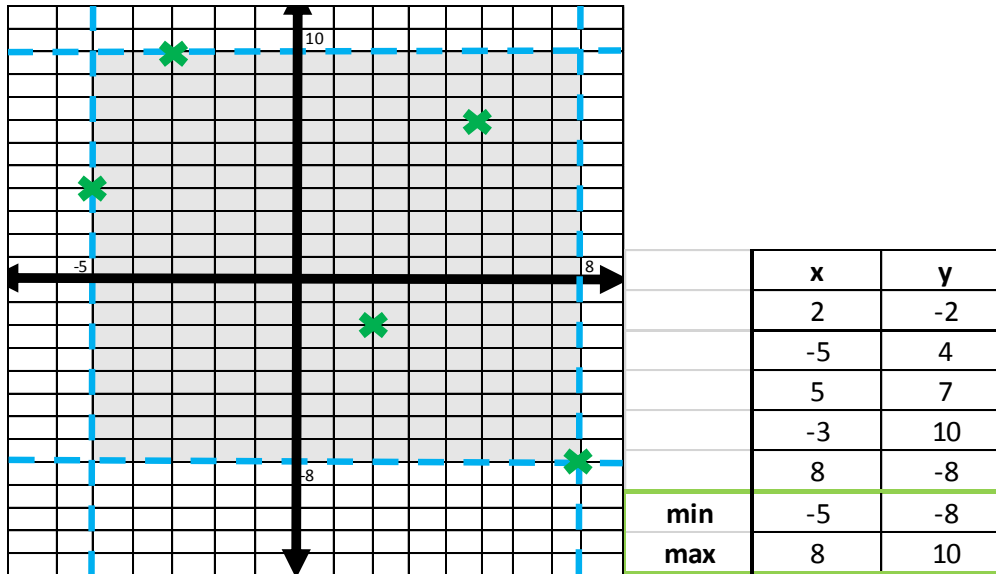
Figure 3: Visual Example of how M^c works and Coordinates Used to Create Graph.

After having an optimization model that worked effectively in a linear way, so that it could be solved with integer-programming solvers, we focused on creating an interface for the asesores, as well as on making the model dynamic using Visual Basic for Applications (VBA). This means making the model adaptable for varying number of scheduled meetings and days, and still run effectively. In addition we included some error-handling features to enhance the tool.

Testing

After the completion of the scheduling tool, our team showed it to different managers of the organization to get feedback. Once they approved the tool we requested them to ask ten asesores to track their visits for a whole week taking notes on the ID of the visited client, the name, and the duration of the meeting. After obtaining all these records we ran our tool with the same visits each asesor completed within that week to obtain an optimal schedule. Then we compared both schedules to measure the impact of the scheduling tool in terms of mileage and transportation time.

Implementation

Once the tool was finalized and the tests were completed, we met through Skype with management in FP to explain the purpose of the tool, the logic it follows and the way it should be used. One manager from FP, ran the tool so others could see the way it works and the potential it has to improve the efficiency of their work. We provided FP with an info packet, which contained instructions to run the tool, instructions to download necessary software, and a PowerPoint with detailed explanations of each tab.

3.3.2 Redistribution of the Microfinance Program's Client Committees

Through our interviews to FP's administration conducted in January 2016, our team understood the redistribution of client committees was also a challenge to be addressed. FP wanted to geographically limit each office, reducing the number of asesores that have client committees in another office's zone.

The leadership at FP determined zones in Google Maps to geographically limit the 24 offices. Figure 4 shows the representation of these newly determined zones. These divisions were determined using local knowledge of traffic, public transportation, and streets. FP's objective when determining the zones was to limit the distance asesores have to travel to meet with client committees within their zone.
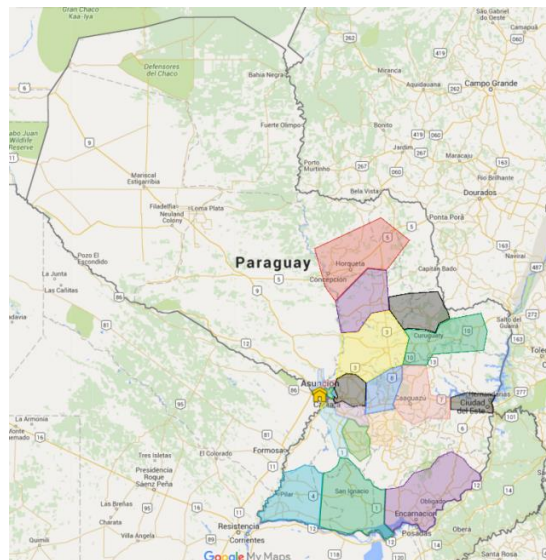
Figure 4: Zones determined by FP Officers for Each Office

Ray Casting

Our task was to provide FP with an analysis of the impact reassigning current client committees to the different zones would have on the program and its client committees. We first had to reassign the client committees to the offices that covered their area. We did this by extracting the coordinates of the arbitrarily shaped polygons FP managers created in Google Maps that represented the different offices of FP. The coordinates were in XML format, which we transferred to excel and organized as a list of latitudes and longitudes for each office. We used each list of coordinates to determine which client committees lied within each polygon. We utilized a method called Ray Casting, which determines whether a point is inside or outside a polygon. Ray Casting tests how many times a ray that initiates in a point intersects with the edges of a polygon. As seen in Figure 5 if the ray has an odd number of intersections, the point is inside of the polygon. If it has an even number of intersections, the point is outside of the polygon.
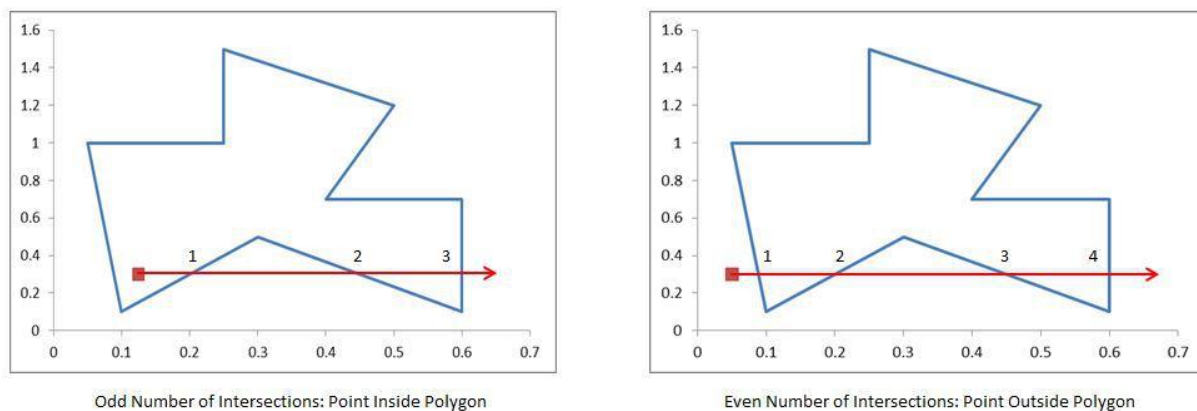
Figure 5: Ray Casting Method Functionality (Songa, 2014)

We used Bander Songa's Ray Casting Excel tool, which allowed us to input the coordinates for each polygon (office) and test all the client committees' coordinates to determine which client committees belong to each zone (Songa 2014). The tool plotted the coordinates we input for the polygons in a Cartesian plane where latitudes were x-coordinates and longitudes were y-coordinates. The test results were true if the point was inside the polygon or false if it was outside the polygon. We followed this procedure for each zone.

Once all of the client committees were assigned to a zone, we determined which ones moved offices. We assigned a 1 to the client committees who moved and a 0 to the ones who stayed in the same office. Then, we did a flow analysis by creating a From/To chart that calculated the amount of client committees that went from office x to office y. Afterwards, we calculated the total number of incoming, outgoing, and staying client committees for each office. We used this to calculate the current state and future state number of client committees in each office and calculate the difference between the current and the future scenarios. This was also used to calculate the total loan amounts of incoming, outgoing, and staying client committees for each office.

We also made a decision making tool that included a summary report for each office. The report includes information of all the client committees that are outgoing, incoming, and staying in each office. We included calculations for key metrics such as counts of how many client committees were outgoing, incoming, and staying and what that represents in loan amounts. A key feature of the tool is a sensitivity analysis that allows managers to reevaluate client committees that are more valuable than others based on a high loan amount.

Implementation

FP managers were interested in using the analysis of the impact of the redistribution of client committees and the decision making tool to reassign their client committees in a way that would decrease the total distance between offices and client committees. Furthermore, they want to repeat this analysis with their other programs including their individual loans program. For this reason, we created an info packet on how to understand the analysis and how to use it to make decisions, including how to use the sensitivity analysis in each office's report. Through a Skype meeting with FP managers, we delivered this info packet and answered questions they had about the analysis and decision making tool. We also made a step–by-step guide on how we did the analysis so they could repeat it with their other programs.

4. Results

This section discusses the components that led the team to further understand the current situation of Fundación Paraguaya. It explains how we defined the challenges we were going to address and how we came up with the solutions. Finally, it focuses on the optimization of asesores' scheduling process and the analysis of reassignment of client committees. For each of these results, the team determined the impact it has on the project.

4.1 Understand the Operations of Fundación Paraguaya's Microfinance and Poverty Stoplight Programs and Identify Challenges and Areas of Improvement

This section shows the results obtained from visiting FP, conducting interviews to key stakeholders, and shadowing asesores. These led the team to further understand the functions of FP and to identify the areas of improvement that would serve as the project focus.

4.1.1 Visit to Fundación Paraguaya

The team visited Fundación Paraguaya between January 6th and January 13th of 2016 to understand the current situation of FP and determine which challenge(s) we were going to address. We had the opportunity to be in the main office and talk to leaders of both the microfinance program and the Poverty Stoplight program as well as the founder of the organization, Martin Burt.

Through this visit, we were able to understand the organization's work environment and daily operations so we could develop a solution that would be useful and attractive for them. Figure 6 includes a general structure of the microfinance and poverty stoplight programs.
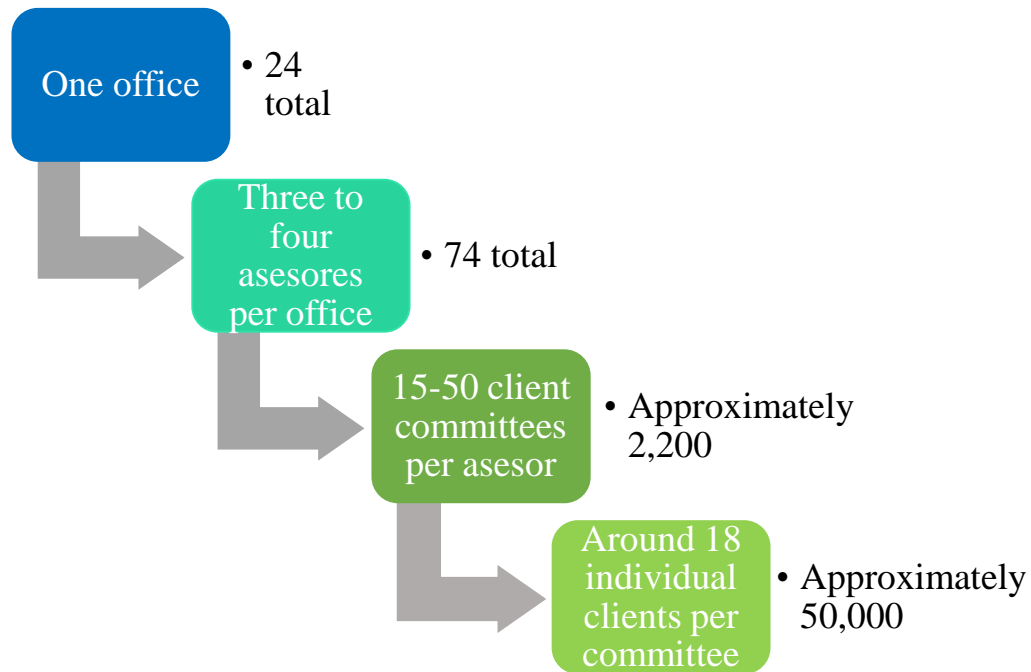
Figure 6: Hierarchical Structure of the Microfinance Program

Implications

Physically going to Paraguay allowed our team to understand the real problems the organization was facing and the scope of feasibility of a project to be developed. Learning about the structure of the organization allowed us to understand how the challenges of the asesores and client committees' distribution fit within the big picture.

4.1.2 Interviews

In our first meeting with FP's administration, the representatives gave us an overview of the microfinance program logistics. The program has two major components: individual loans and group loans. Our team was assigned to work with the group loans program. During this meeting, some representatives expressed the challenge of not having specific zones for each office. In its current state, asesores from different offices go to the same areas to look for new client committees and to visit their own. For this reason, the administration intends to create an optimal zoning plan to limit each office. Determining zones for each office implies that many asesores will be impacted and will have to change their client committees based on the modifications these new zones suggest. The main limitation mentioned by the administration towards changing client committees, was the bonds of trust between client committees and asesores. Most asesores would not trade their client committees with other asesores even if this change will increase their efficiency. Another challenge was the lack of an organized process to schedule client committees' meetings.

23

During this meeting we also learned about all the different activities asesores are responsible for. Figure 7 presents a summary of all the meetings and activities an asesor does monthly. All the types of meetings are value added activities as they add value to the client committees. Activities that fall in the administrative work criteria and other activities criteria are non-value added activities. This means that process improvements can help decrease the time invested in those non-value added activities.

Types of Meetings	Administrative Work	Other Activities
New Committees (4)	KIVA	Transportation to meetings
Existing Committees (Varies)	Paperwork for all committees	
Late Payers (Varies)		Promotion of program
Renewal or Canceling Credits (Varies)	Scheduling Meetings	
Poverty Stoplight Meetings (35)		
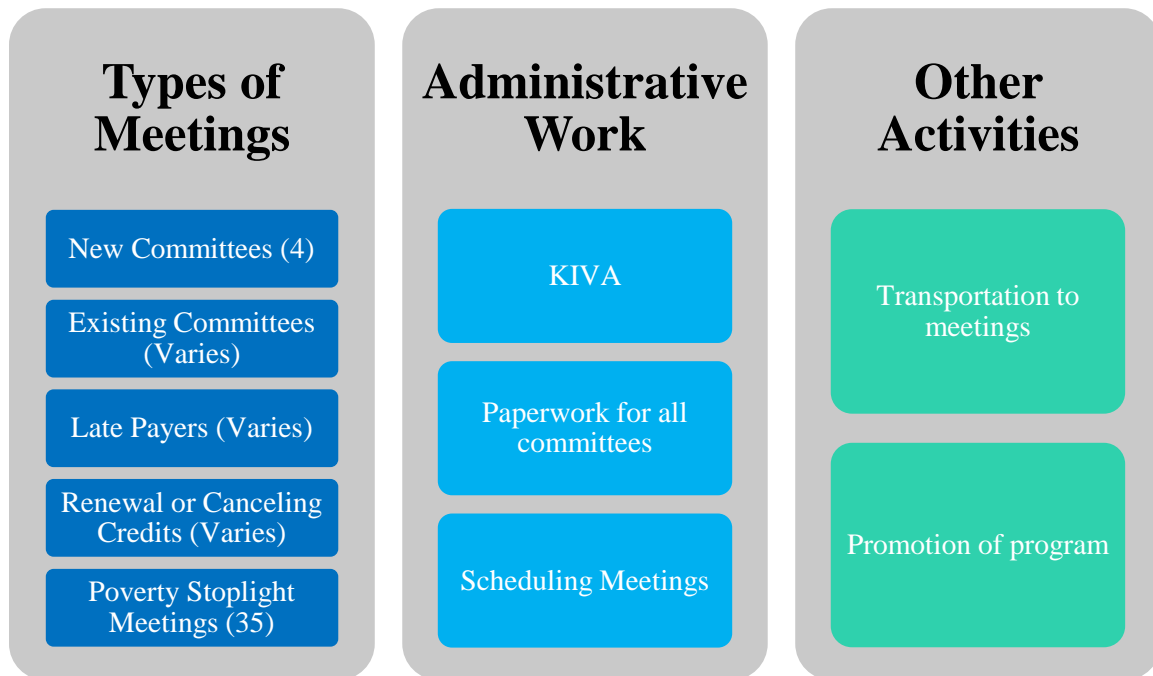
Figure 7: Summary of Asesores Meetings and Activities

Our second meeting was with the general manager of the microfinance program. He explained the reason asesores travel further distances to get to client committees. In FP's microfinance program each office and asesor has production goals set for them in terms of number of client committees they need to reach. If an asesor is not able to get enough client committees to meet the goal, they have to travel further distances to get client committees. Each committee is usually composed of 17 or 18 women who get a group credit in which each pays an individual fee of their choosing. They get a credit for four months and then it is either cancelled or renewed. He mentioned that the impact of the program's inefficiencies was the time wasted while traveling long distances to visit client committees on a daily basis. This time could be reduced if asesores scheduled meetings that were closer together on the same day and if offices had a geographical limit. In addition, we discussed with the manager the possibility of implementing a tool to help asesores create efficient routes for each day. He mentioned asesores won't have more than four meetings in a day and asesores are capable of determining their own routes. Another solution we

discussed was the reassigning of all client committees based on their location and he emphasized the difficulty of executing these changes. Nevertheless, the manager mentioned that if FP's administration was interested in moving forward with the redistribution of client committees it would be implemented.

The third group of meetings we had was with the managers of the individual offices who explained several aspects of the program. First, when the program started, FP only had a few offices. As FP started to expand, they never transferred client committees to the appropriate office, nor set geographical limits to each office. Therefore, asesores ended up having client committees not only in their zone but in all its surroundings. Second, as we heard in the previous interview, asesores travel further distances to meet their goals. In addition, client committees are mostly acquired through referrals of other client committees and these may be in other zones. Third, one of the managers showed us an example of the amount of monthly meetings an actual asesora has per month. These are shown in

Table 1. He also mentioned the responsibilities each asesor has may vary depending on the amount of time they have worked as an asesor. For example, new asesores will spend more time advertising the program to get client committees than tenure asesores. Fourth, the manager mentioned that each asesor makes his or her own schedule, most of the times based on client availability.

The following table represents the monthly meetings of an asesora named Mariana. This asesora was in charge of 69 committees, which is around 1,104 individual clients. The total meetings per month were 78 which averages to 3.9 meetings per day if using a 20 working day month. When we were in Paraguay, we realized that having 3.9 meetings per day is highly unlikely and probably impossible due to long distances they have to travel, especially when the meetings are far apart from each other. This results in asesores working overtime as well as weekends.

Table 1: Example of an Asesor's Monthly Meetings

Types of Meetings	Number of Meetings (Monthly)
Renewal	13
Poverty Stoplight	35
Late Payers	12
New Committees	8
Follow-up	10
Total Meetings per Month	78
Average Meetings per Day (based on 20 working days)	3.9

During our fourth meeting, we met with the HR trainer for the Poverty Stoplight program. The main takeaways from this interview were learning that every office runs differently depending on each manager, and that the three priorities of the programs were to give emphasis to new committees, give more follow-ups to bad committees, and get client committees for the Poverty Stoplight program.

In our final interview, we met with asesores from different offices. In summary, from these interviews we learned asesores make their own schedules and attempt to balance the different activities and meetings. To move around, some use public transportation, others use private cars, and others use motorcycles. Their main challenge is the amount of responsibilities they have and the lack of time to complete these activities. The asesores we interviewed were open to change their way of completing their tasks if it implied an increase in efficiency.

Implications:

Interviewing Martin Burt, managers, and asesores enabled us to define the scope of the project with the input of all parties involved. We were able to understand the need for improvement in the organization of the asesores and the consequences of the lack of zoning of the client committees.

There were four main takeaways from these interviews. First, asesores have numerous activities and responsibilities and therefore are working excessive hours. Second, asesores travel long distances to meet their clients that are scattered all around the region. Third, asesores have meetings that are very far apart from each other on the same day. Finally, asesores are open to change their organization methods for the improvement of their work.

4.1.3 Shadowing an Asesor

Another opportunity in Paraguay was shadowing an asesora for half of a day in the Villa Elisa office. We arrived early in the morning to the office and interviewed Amalia to learn about the different activities she conducts every day. We gained a better understanding of the amount of administrative work that asesores need to do apart from the client committee visits. On this particular day, Amalia was going to conduct two visits: one in the morning and one in the afternoon. The morning one was in Villeta, which according to Google Maps is 45 minutes away. This estimate is accurate when using personal transportation, which is not common for asesores in urban offices. In Figure 8, we broke down all of the activities of this visit and their corresponding completion times.
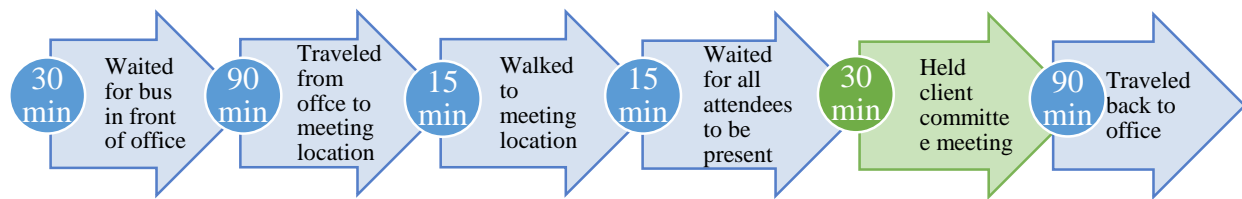
Figure 8: Breakdown of Activities during Committee Visit

We traveled to Villeta using public transportation (bus), which took around 30 minutes to arrive to the station where we were waiting, and one and a half hours to get to Villeta. After our arrival, we walked on a dirt road for around 15 minutes until we arrived to the house of the client committee president. After we got there, we waited around 15 more minutes until all the members of the group (except for one) arrived. The purpose of that meeting was to put pressure on the group because they were late on their payment. The meeting lasted for around 30 minutes, after which we took the bus back to the Villa Elisa office. We waited again around 15 minutes for the bus and the ride back took around 1 hour and a half again. After this experience, we were able to understand that even though the meeting only lasted 30 minutes, more than 3 hours were used on transportation. The blue arrows in Figure 8 represent waiting and transportation which are non-value added activities. The only value-added activity is shown in the green arrow which was the actual meeting.

Implications

After shadowing an asesora, we understood the challenge of commuting to and from meetings. We also confirmed that scheduling meetings that are far apart from each other on the same day worsens the situation. We understood that distances are not directly related with the time of travel stated in Google Maps due to irregularities in the roads, traffic, and the differences in modes of transportation.

This experience confirmed the need to group nearby meetings in the same day to avoid traveling long distances for a single meeting. In addition, we gained first-hand experience concerning the connection asesores have with their client committees, which is based on trust and respect, and how it raises a challenge when considering reassigning clients.

4.2. Evaluate Existing Challenges and Determine Solutions

Our team determined the challenges we were going to address, evaluated potential project options, and determined the feasibility of initial solutions, and presented findings and potential solutions.

Before arriving to Paraguay we had two project ideas: determining the best route for an asesor once the client committees to visit are known for that day, and allocating resources in Asunción based on

Poverty Stoplight data. Both ideas deemed as not feasible for different reasons. First, because asesores rarely meet more than four client committees in a day, determining the best route for such a small number of meetings would not add much value. Second, the Poverty Stoplight program consists of empowering people to improve their own quality of life, rather than distributing resources.

During our first meetings with FP managers we were notified the lack of zoning of client committees was an issue FP was interested in addressing, but after interviewing some managers and asesores, we understood it was important but not the only thing we could do. Based on the people we interviewed, we determined which of the major challenges could be addressed with Industrial Engineering techniques. We narrowed the challenges down to an individual challenge and an organizational challenge, therefore making an impact on both the day-to-day activities of the asesores, as well as the overall path of the organization. The individual challenge was the lack of organization of the asesores in terms of scheduling meetings, and the lack of an electronic agenda. To address this challenge, we decided to develop a scheduling tool that groups selected meetings into groups based on proximity and allows asesores to create a more optimal schedule. The organizational challenge was the lack of zoning and the problem of having asesores from one office visit other offices' areas to meet with their client committees. To address this challenge, we simulated the assignment of client committees to offices based on their geographical location using Bander Songa's ray casting tool, we analyzed the impact of these changes, and we provided FP with a decision-making tool. Figure 9 explains the path our project will take.

Individual Challenge:
Lack of Planning

↓

Scheduling
Optimization Tool

Organizational Challenge:
Zoning Inefficiency

↓

Analysis of Impact and
Decision Making Tool
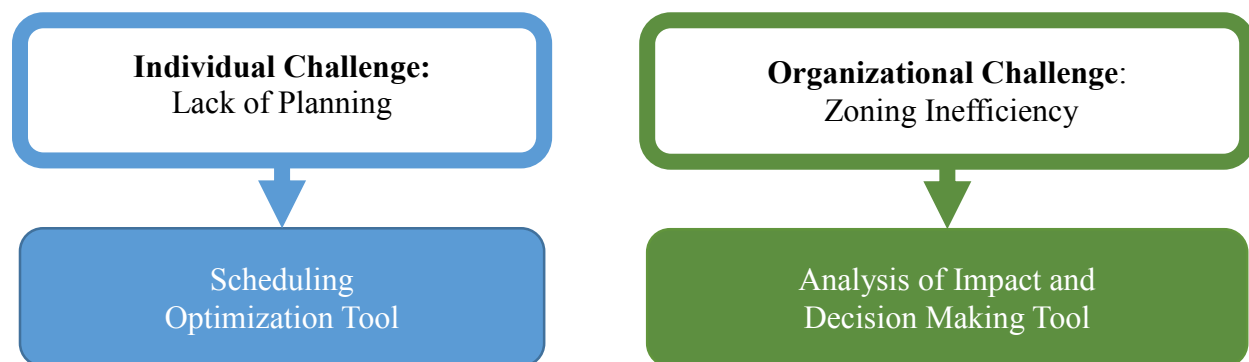
Figure 9: Challenges Addressed during our Project

After determining the approach we wanted to follow, our final meeting in Paraguay was a presentation to FP management. We obtained their feedback, and received their approval to proceed with these two projects. Once we arrived to WPI, we determined with the help of our advisor Professor Trapp, that a proximity based clustering approach was going to be the starting point of our scheduling tool. This

way, meetings could be grouped based on proximity with the objective of minimizing the distance traveled.

Implications

Evaluating the challenges led us to focus our project in the organization of the asesores and the redistribution of clients. This analysis led us to focus on what FP management indicated was a challenge, further underscoring what we personally observed the asesores needed to become more efficient and, as a consequence, find more balance in their lives and activities.

4.3 Solutions that improve the efficiency of the Microfinance and the Poverty Stoplight programs and Implementation Plans

This section discusses the two solutions we developed: the optimization of the scheduling process and the redistribution of client committees.

4.3.1 Optimization of Scheduling Process

This section includes the model logic, the Excel scheduling tool description, the application of VBA, and the impact of the tool.

Model Logic

Our Scheduling Tool model seeks to minimize the total distance traveled by asesores by assigning meetings that are closest to each other on the same days. Some of the constraints include that days have a minimum and maximum number of meetings, each meeting gets assigned to exactly one day, and the total meeting time per day cannot exceed a time determined by the asesor. The algebraic model used to build this optimization based tool can be found in Section 3.2.1. As a result of this tool, a new scheduling process was created, as depicted in Figure 10.

1. Create a database with client information including latitudes and longitudes
2. Input client ID's and meeting time for selected client committees
3. Determine number of days and create schedule
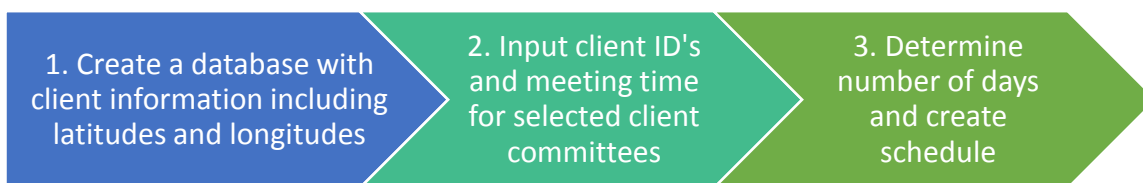
Figure 10: New Scheduling Process

The objective of this tool was to reduce the amount of times an asesor has to travel to the same zones on different days of the week as well as, indirectly, reduce the amount of time an asesor spends on traveling to get to each meeting.

We developed an optimization tool using Microsoft Excel, OpenSolver, and Visual Basic for Applications (VBA) that employed the clustering algorithm explained in our methodology (Section 3.3.1). We designed the tool in Spanish using recommendations gathered during our visit and aimed to make it as user friendly as possible. The tool is intended to be used by asesores who wish to schedule meetings with a number of client committees for a specific number of days. The tool provides asesores a suggested schedule of the days they wish to schedule for and shows which client committees should be scheduled together.

The tool includes four main tabs. Figure 11 shows the *Selected Clients* tab where the asesor picks which client committees he or she would like to meet for the specified number of days. The tab includes buttons to help the asesor perform different operations. These include a button to re-start (which clears all the data in the tab), a button to manually enter client committees' IDs and duration of meetings, a button to show the names of the client IDs entered, and a button to create the schedule. In this tab the asesor will input or copy and paste the ID number for the selected client committees into the first column and then click the button "Check Names" to verify that the IDs entered correspond to the correct client committees. The asesor also has the option of clicking the "Add Client" button to manually enter the client IDs and the duration of the meetings one by one. Once all the information has been input (that is, the client IDs and the duration of all the meetings), the asesor is ready to create the schedule by clicking the "Create Schedule" button and specifying the number of days to schedule.

Client ID	Client Name	Approximate Meeting Time (Minutes)	
1742857	Damasia Avalos	30	
3547775	Josefina Rios	30	Re-Start
5108410	Noemi Quiñonez	30	
820386	Jacinta Ojeda	30	Add Client
905046	Lucia Rodriguez	30	
3880475	Cristina Rodriguez	30	Check Names
2008632	Graciela Torres	30	
1478965	Patricia Palma	30	Create Schedule
4428045	Julia Cabrera	30	
889165	Teresa Martinez	30	
1059030	Andresa Britez	30	
1579341	Isabel Sanchez	30	
2662300	Mariana Saldivar	30	
3000733	Sonia Gimenez	30	
6854064	Nilsa Mancuello	30	

Figure 11: Selected Clients Tab

Figure 12 shows the *Database* tab where all the client information is stored. Each asesor will have a personal *Database* tab where they can include their specific client committees. The tab and the optimization model require the following information to run: client ID, name of client, latitude, and longitude. Asesores will only need to copy and paste this information from their two databases (Poverty Stoplight and Microfinance). This tab allows the model to cross reference the geographical information of each client that will be used to cluster the meetings.

Client ID	Client Name	Latitude	Longitude
1742857	Damasia Avalos	-25.306954	-57.418549
3547775	Josefina Rios	-25.268936	-57.491822
5108410	Noemi Quiñonez	-25.294604	-57.521281
820386	Jacinta Ojeda	-25.294604	-57.521281
905046	Lucia Rodriguez	-25.217808	-57.442108
3880475	Cristina Rodriguez	-25.304886	-57.43138
2008632	Graciela Torres	-25.314244	-57.389324
1478965	Patricia Palma	-25.293973	-57.417941
4428045	Julia Cabrera	-25.210921	-57.448296
889165	Teresa Martinez	-25.274551	-57.506792
1059030	Andresa Britez	-25.287521	-57.521024
1579341	Isabel Sanchez	-25.303753	-57.415289
2662300	Mariana Saldivar	-24.813466	-56.52333
3000733	Sonia Gimenez	-24.684067	-56.390261
2959883	Inocencia Insaurralde	-24.191004	-56.605805
3677880	Pelagia Martinez	-24.300913	-56.423556
5237440	Liza Franco	-24.474235	-56.118732
2112120	Cresencia Esquivel	-24.683043	-56.392931
2426425	Daniela Franco	-24.973512	-56.307206
6854064	Nilsa Mancuello	-24.65923	-56.438016
5707903	Aline Duarte	-24.81529	-56.72881
1315215	Maria Estigarribia	-24.816322	-56.733656
3473561	Marta Silva Alviso	-57.14265	-25.332612
4881686	Nancy Elizabeth Morales Meza	-57.131196	-25.376552
826051	Rumilda Montiel	-57.190521	-25.374004
4079882	Alba Mercedez Morales Amarilla	-57.071449	-25.253105
2681664	Lidia Aquino Vargas	-57.062654	-25.284268
3416869	Yohana Iris Paez Ortiz	-57.086994	-25.265919

Figure 12: Database Tab

Figure 13 shows the *Settings* tab where asesores or managers will be able to change the minimum number of meetings, the maximum number of meetings per day, and the maximum meeting time that should be allowed by the model. This tab also includes other parameters that are needed for the VBA code such as a count for number of client committees and number of days.
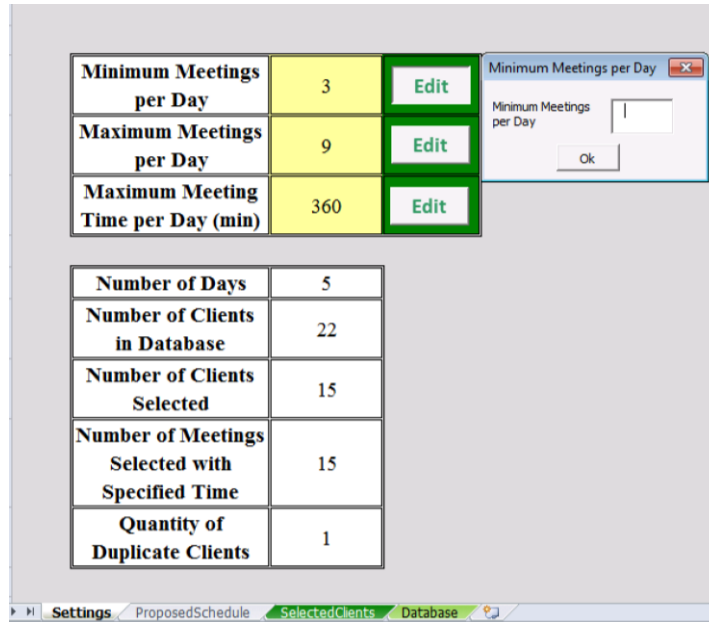
Figure 13: Settings Tab

The fourth tab is the *Proposed Schedule* tab, which is essentially the output of the model. This tab is created each time the model runs, which occurs when the asesor clicks on the Create Schedule button. It displays the different clusters of client committees created by the optimization model. The names of the client committees are shown below a heading "Day x" as shown in Figure 14. The use of optimization ensures that all the client committees in a group are closer to the client committees in the same group than to the client committees in other groups.

Day 1	Day 2	Day 3	Day 4	Day 5
Noemi Quiñonez	Josefina Rios	Damasia Avalos	Mariana Saldivar	Lucia Rodriguez
Jacinta Ojeda	Patricia Palma	Graciela Torres	Sonia Gimenez	Cristina Rodriguez
Andresa Britez	Teresa Martinez	Isabel Sanchez	Nilsa Mancuello	Julia Cabrera

Figure 14: Proposed Schedule

Using VBA

To develop this tool, we used OpenSolver and VBA. OpenSolver is a free Excel add-in that enables the formulation and solution of mixed-integer optimization problems in Excel. It uses CBC, a free open-source solver, to optimize problems (Mason 2012) . This allows the tool to create a schedule for the asesores to follow, based on number of client committees selected and number of days determined which might change every time. Through VBA we were able to provide this flexibility to our tool by creating variables in the code named *NumClient* (number of client committees) and *NumClusters* (number of

days). These variables referred to cells in the *Settings* tab that counted the number of client committees selected and the number of days determined respectively. Our entire code can be found in Appendiz B.

VBA also allowed us to improve our tool with error-handling capabilities. We inserted message boxes for the following errors that might occur when using the model, as shown in Table 2.

Table 2: Possible Errors and their Message Boxes

Error	Error Message
Duplicates in clients selected	"Delete one of the client committees highlighted in red"
Duration of a meeting is not specified	"All selected client committees need a specified duration of meeting"
Selected client committee is not in database tab	"Check IDs of selected client committees or add client to database tab"
Selected client committees divided by number of days is smaller than minimum meetings per day	"Reduce the number of allowed meetings per day or schedule for less days"
Selected client committees divided by number of days is larger than maximum meetings per day	"Increase the number of allowed meetings per day or schedule for less days"

Impact

In order to determine the potential impact of our tool in the organization, we collected a weekly schedule for ten asesores, and compared these ten schedules with ten schedules that the tool suggests, based on mileage and transportation time. Both groups of schedules were created based on the same meetings and number of days for each case. We created maps for both schedules for the ten different cases and indicated each day with different colors. From these maps we were able to calculate the distance and time traveled each day by creating driving routes from the main office to the meetings, coming back to the office at the end of the day.

Figure 15 shows the schedule created by an asesora in Luque (a) and the same schedule created with our tool (b). In these figures, the clustering concept is evident as the meetings that are closest are grouped together. Map (a), shows meetings on the same day scattered around the area as indicated by the yellow, blue, and purple dots. Comparatively, map (b) shows the tool-scheduled meetings that are closest to each other are grouped together as shown with the colored dots. In this specific case, the total reduction in distance by using the tool was 50.9% and the reduction in time traveled was 46.47%.
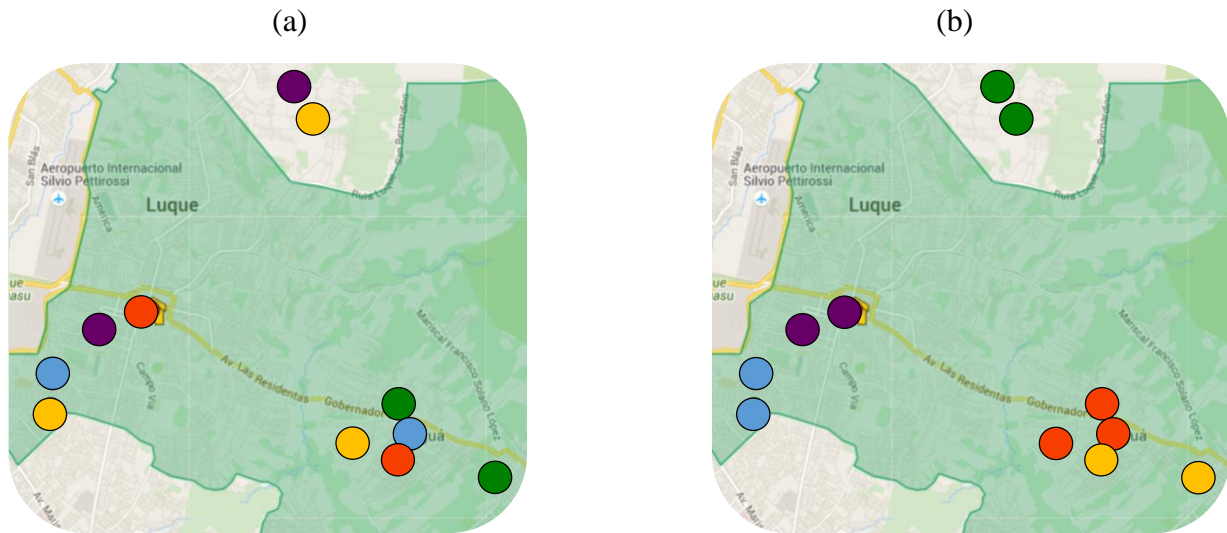
Figure 15: Schedule of an Asesor in Luque and Schedule of Luque's Asesor Made with the Tool

In addition to the maps, we created a summary of the impact of the schedule created with the tool for all ten records which can be found in Table 3. The ten schedules we received from FP can be found in Appendix C.

Table 3: Comparison between Asesores' Schedule and our Tool's Schedule

Office Name	Number of Days	Number of Visits	Miles Traveled with Asesor's Sechedule (mi)	Miles Traveled with Tool's Schedule (mi)	Percentage Difference	Travel Time with Asesor's Schedule (min)	Travel Time with Tool's Schedule (min)	Percentage Difference
Luque	5	11	108.83	53.77	-50.59%	340	182	-46.47%
Paraguarí	2	4	78.81	55.55	-29.51%	180	136	-24.44%
Ybycuí	3	5	122.86	89.29	-27.32%	227	167	-26.43%
San Lorenzo	5	10	112.96	83.38	-26.19%	355	278	-21.69%
Asunción	4	9	53.318	41.926	-21.37%	242	178	-26.45%
Coronel Oviedo	2	5	10.32	8.63	-16.38%	48	40	-16.67%
Encarnación	3	5	118.36	103.33	-12.70%	249	219	-12.05%
Santaní	5	10	294.786	280.66	-4.79%	446	431	-3.36%
Concepción	1	3	7.04	7.04	0.00%	37	37	0.00%
Ciudad del Este	3	4	14.17	14.25	+0.56%	55	55	0.00%
Total	33	66	921.454	737.826	19.93%	2179	1723	20.93%

As showed in Table 3, the total reduction in distance by using the tool was 19.93% and in terms of reduction of time it was 10.93%. In addition, there are some offices such as the Luque office where the mileage reduction was 50.5%, significantly higher than other offices. On the other hand, the office of Concepción did not present any changes in the schedule because the schedule was completed for only a single day. Also, the office of Ciudad del Este actually showed an *increase* of 0.08 miles when the schedule is completed with the tool but the time of travel remains the same. This minor, negative anomaly is simply because the grouping suggested by the tool requires the asesor to go through a less direct path to reach its destination.

For this analysis we included the ten records of schedules FP provided us. This analysis omits duplicates found in each record, as well as client committees who did not have geographical references.

Implications

Through our limited experimentation, this tool has the potential to impact the work of 74 asesores on a weekly basis by reducing approximately 21% of the time they spend traveling and allowing them to use that time to either meet with more committees, complete other tasks, or find balance in their lives. The tool also has the potential to decrease the mileage traveled by approximately 20%, which will end up decreasing the amount of Guaraníes (Paraguayan currency) spent in transportation by the organization and the asesores.

4.3.2 Redistribution of FP's Microfinance Program's Committees

In this section we discuss the analysis of reassigning committees to their respective geographical zone (determined by FP) in terms of the client committees and the loans that moved to another office, and a summary of the analysis. We also discuss the results of the decision making tool we created to aid FP managers in making decisions and an implementation plan for this deliverable.

Analysis of Reassignment

After we reassigned committees to their appropriate zone, we organized the information in a table as shown in the Figure 16. We divided the table into three sections which are color-coded each as follows: client information in dark blue, current office information in light blue, and future office information in green. The client information included the client IDs, client name, their respective loan size, and their latitudes and longitudes. The current office information included the current office number, the current office name, the latitudes and longitudes of the current office, and the distance to the current office. The future office information includes the future office number, the future office name, a calculation of whether or not the committee changed from one office to another, the latitudes and longitudes of the future office, and the distance to the future office. This table was a result of the ray casting analysis done

for all committees for each of the 24 zones. It was used to determine and count which committees changed and which committees stayed in the same office.

Client Information						Current Office Information					Future Office Information					
Client ID	FP Id	Name	Loan Size	Latitude	Longitude	Current Office Number	Current Office	Latitude (Current Office)	Longitude (Current Office)	Distance to Current Office	Future Office Number	Future Office	Changes	Latitude (Future Office)	Longitude (Future Office)	Distance to Future Office
4799276	7644697	RNOFFER AVALOS, DAHIANA MARLENE MONSERR	28524171	-25.358	-57.599	2	Asuncion	-25.30344	-57.6127	6.221082445	20	Lambare	1	-25.34022	-57.59798	1.979700989
4863197	7703562	GASPARINI VERA, KATHERINE MABEL	68309768	-25.353	-57.628	20	Lambare	-25.34022	-57.59798	3.334682644	20	Lambare	0	-25.34022	-57.59798	3.334682644
2208651	7469120	VIERA MEDINA, YENY ESMILCE	67963020	-25.344	-57.6	20	Lambare	-25.34022	-57.59798	0.466770534	20	Lambare	0	-25.34022	-57.59798	0.466770534
829991	7626847	ARCE PINTOS, MARCELINA	35176016	-25.335	-57.603	2	Asuncion	-25.30344	-57.6127	3.64223238	20	Lambare	1	-25.34022	-57.59798	0.7690441
4798853	7755383	MALDONADO DOMINGUEZ, KATIA JAZMIN	18047497	-25.349	-57.607	2	Asuncion	-25.30344	-57.6127	5.0983308	20	Lambare	1	-25.34022	-57.59798	1.332208884
2475977	7571959	LEZCANO DE AREVALO, MARGARITA GENARA	79520391	-25.339	-57.572	2	Asuncion	-25.30344	-57.6127	5.689439954	20	Lambare	1	-25.34022	-57.59798	2.614421405
4831575	7589488	MEDINA DE MERELES, LOURDES MARINA	26408803	-25.353	-57.64	2	Asuncion	-25.30344	-57.6127	6.156106967	20	Lambare	1	-25.34022	-57.59798	4.455329029
4198254	7773228	DIAZ FALCON, NILDA ELIZABETH	18552719	-25.324	-57.573	20	Lambare	-25.34022	-57.59798	3.091247533	20	Lambare	0	-25.34022	-57.59798	3.091247533
1010860	7420859	LOPEZ VDA DE GONZALEZ, TEODORA RAFAELA	39720041	-25.345	-57.583	7	Villa Elisa	-25.35237	-57.57195	1.380067526	20	Lambare	1	-25.34022	-57.59798	1.596475927
2363827	7605153	NUÃ‘EZ GIMENEZ, MODESTA ELIZABETH	25899029	-25.361	-57.606	2	Asuncion	-25.30344	-57.6127	6.435704155	20	Lambare	1	-25.34022	-57.59798	2.447141722
3177185	7745784	REY TORRES, LISLE MONSERRAT	19643311	-25.33	-57.578	20	Lambare	-25.34022	-57.59798	2.307266089	20	Lambare	0	-25.34022	-57.59798	2.307266089
3258230	7595150	ROA CARDOZO, MARIA EMILCE	64702153	-25.36	-57.605	2	Asuncion	-25.30344	-57.6127	6.336618098	20	Lambare	1	-25.34022	-57.59798	2.309792335
3917259	7769496	CARMONA, NILDA ROSSANA	13683113	-25.349	-57.603	2	Asuncion	-25.30344	-57.6127	5.158996689	20	Lambare	1	-25.34022	-57.59798	1.098925236
1940337	7457972	CARDOZO DE ZENA, MARIA LUISA	6654798	-25.343	-57.61	20	Lambare	-25.34022	-57.59798	1.246874141	20	Lambare	0	-25.34022	-57.59798	1.246874141
2109259	7592615	AYALA VALDEZ, IDALINA	84339783	-25.354	-57.639	2	Asuncion	-25.30344	-57.6127	6.212412768	20	Lambare	1	-25.34022	-57.59798	4.397686074
2177234	7747911	ROJAS GONZALEZ, MARIA CONCEPCION	13896299	-25.349	-57.594	20	Lambare	-25.34022	-57.59798	1.055041561	20	Lambare	0	-25.34022	-57.59798	1.055041561
3494363	7781187	DIAZ VDA DE SEGOVIA, VERONICA LUCIA	23747862	-25.337	-57.603	20	Lambare	-25.34022	-57.59798	0.618639669	20	Lambare	0	-25.34022	-57.59798	0.618639669
1616244	7647631	GONZALEZ DENIS, ROSA BLANCA	75888892	-25.355	-57.608	20	Lambare	-25.34022	-57.59798	1.927389127	20	Lambare	0	-25.34022	-57.59798	1.927389127
3417397	7783890	AYALA AQUINO, CINTHIA NATHALIA	13676440	-25.356	-57.614	20	Lambare	-25.34022	-57.59798	2.381261381	20	Lambare	0	-25.34022	-57.59798	2.381261381
851450	7736560	VILLALBA DE DELVALLE, FELIPA MABEL	28973997	-25.349	-57.594	20	Lambare	-25.34022	-57.59798	1.055041561	20	Lambare	0	-25.34022	-57.59798	1.055041561
2586717	7482550	VAZQUEZ DE MACIEL, SANDRA ELIZABETH	26858282	-25.332	-57.592	20	Lambare	-25.34022	-57.59798	1.093902006	20	Lambare	0	-25.34022	-57.59798	1.093902006
793390	7555376	BORDON, MARIA INES	43347771	-25.319	-57.608	2	Asuncion	-25.30344	-57.6127	1.793536097	20	Lambare	1	-25.34022	-57.59798	2.565477065
3642433	7509498	ZORRILLA VILLANUEVA, LIZ MARGARITA	35487305	-25.349	-57.607	2	Asuncion	-25.30344	-57.6127	7.312411984	20	Lambare	1	-25.34022	-57.59798	3.326006082
4184855	7642491	SANTANDER ROBLES, LIZ MARIA	37699183	-25.349	-57.607	2	Asuncion	-25.30344	-57.6127	5.0983308	20	Lambare	1	-25.34022	-57.59798	1.332208884
636540	7549099	CANO PARODI, VENANCIA CONCEPCION	43040110	-25.318	-57.61	2	Asuncion	-25.30344	-57.6127	1.641589416	20	Lambare	1	-25.34022	-57.59798	2.750282177
3602363	7757014	AGUERO AVALOS, MONICA MONSERRAT	16398047	-25.347	-57.621	20	Lambare	-25.34022	-57.59798	2.433099106	20	Lambare	0	-25.34022	-57.59798	2.433099106
1835377	7453811	VARGAS, JULIANA	34090722	-25.359	-57.62	2	Asuncion	-25.30344	-57.6127	6.221401897	20	Lambare	1	-25.34022	-57.59798	3.042534051
1347396	7435937	ORTIZ DE GONZALEZ, NILVIA ROSSANA	35785363	-25.35	-57.6	2	Asuncion	-25.30344	-57.6127	3.734270359	20	Lambare	1	-25.34022	-57.59798	0.614914049
3315988	7683012	GALEANO FRANCO, NOELIA CONCEPCION	20769319	-25.367	-57.613	2	Asuncion		-57.6127	7.067613848	20	Lambare	1	-25.34022	-57.59798	3.338447051

Figure 16: List of all Client Committees Included in the Analysis

Analysis of Client Committees Flow

Next, we analyzed the committees that moved to another office by making a flow analysis. This consisted of creating a From/To chart found in Figure 17.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2	0	5	0	0	0	18	0	0	0	0	0	3	0	1	0	0	0	0	25	0	0	0	0	0	0
3	0	0	0	1	7	7	0	0	0	0	0	0	0	24	0	0	0	0	1	0	0	0	0	0	0
4	0	0	0	0	2	0	0	0	0	0	1	0	0	1	0	0	0	8	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
6	0	0	2	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
7	3	24	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	8	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	25	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	1	0	0	1	
19	1	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
20	5	7	0	1	0	14	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 17: From/To Chart of Client Committees that Moved to another Office

Figure 17 shows the amount of committees that left one office and entered another, hence the from/to concept. The bold numbers on the left represent the *From* offices and the bold numbers on the top represent the *To* offices. The table can be read as follows: *5 committees left office 2 and entered office 3*. The cells highlighted in yellow show the amount of committees that moved from the respective office in the left and entered the respective office in the top row. In the table there is no number 1 because office 1 represents the headquarters of FP which does not participate in the Microfinance program. The information from the From/To chart is summarized in Table 4.

Office #	Office Name	Committee Flow Analysis			Current and Future Scenarios		
		From	To	Stayed	Before	After	Difference
2	Asunción	52	20	21	73	41	-32
3	San Lorenzo	40	61	68	108	129	21
4	Caacupé	12	2	116	128	118	-10
5	Carapeguá	3	10	98	101	108	7
6	Luque	14	9	83	97	92	-5
7	Villa Elisa	35	43	34	69	77	8
8	San Ignacio	0	0	59	59	59	0
9	Encarnación	0	0	171	171	171	0
10	Ciudad del Este	1	0	138	139	138	-1
12	Villa Hayes	0	3	16	16	19	3
13	Mariano Roque Alonso	10	15	75	85	90	5
14	Caaguazú	0	6	186	186	192	6
15	Itá	35	39	104	139	143	4
16	Ybycui	0	2	37	37	39	2
17	Coronel Oviedo	1	14	75	76	89	13
18	Santaní	17	1	141	158	142	-16
19	Paraguarí	5	10	68	73	78	5
20	Lambaré	36	30	18	54	48	-6
21	Pilar	0	0	68	68	68	0
22	Villarrica	5	0	41	46	41	-5
23	Concepción	0	1	69	69	70	1
24	Villa Ygatimí	0	0	9	9	9	0
25	Curuguaty	1	0	33	34	33	-1
26	San Pedro	0	1	60	60	61	1

Table 4 was done by summing up the rows and columns of the From/To chart in Figure 17. The left-hand side of the table summarizes the changing committees flow analysis. The *From* column is a result of the sum of each row and the *To* column is a result of the sum of each column. The office of Asunción was the office to lose the most committees (52). On the other hand, the office of San Lorenzo was the one to gain most committees (61). The office of Caaguazu was the office in which the most committees did not change (186). It was also one of the nine offices that did not lose any client committees; this is largely because of its remote location with respect to the other offices.

The right-hand side of Table 4 summarizes the *Before* and *After* reassignment scenarios for each office. The *Before* column shows the amount of committees for each office before the reassignment and consists of the sum of the *From* and *Stayed* columns. The *After* column shows the amount of committees for each office after the reassignment and is a result of the sum of the *To* and *Stayed* columns. The *Difference* column shows whether offices ended up gaining or losing loans and the ones that lost are highlighted in pink.

Analysis of Loan Amount Flow

We did the same flow analysis with loans in dollars. The From/To chart in Figure 18 shows the sum of the loans moving from one office to another. This information is summarized in Table 5.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2	$0	$35,995	$0	$0	$0	$137,259	$0	$0	$0	$0	$21,009	$0	$7,855	$0	$0	$0	$0	$0	$167,453	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$3,095	$33,235	$37,683	$0	$0	$0	$0	$0	$0	$0	$147,690	$0	$0	$0	$0	$2,770	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$11,768	$0	$0	$0	$0	$0	$7,944	$0	$0	$7,735	$0	$0	$0	$43,114	$0	$0	$0	$0	$0	$0	$0
5	$13,419	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$5,678	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
6	$0	$0	$5,570	$0	$0	$0	$0	$0	$0	$0	$0	$91,717	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$10,850	$102,587	$0	$7,390	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,605	$0	$0	$0	$0	$22,533	$0	$0	$0	$0	$0	$0
8	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
9	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,870	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
13	$30,655	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,333	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
15	$0	$159,285	$0	$16,756	$0	$23,196	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,299	$0	$0	$0	$0	$0	$0	$0
16	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
17	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,464	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$2,881	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$75,320	$0	$0	$0	$0	$0	$0	$4,183	$0	$0	$3,428
19	$1,129	$0	$0	$13,118	$0	$0	$0	$0	$0	$0	$0	$0	$3,296	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$17,603	$40,646	$0	$9,255	$0	$74,491	$0	$0	$0	$0	$0	$0	$42,101	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
21	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
22	$3,956	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$11,370	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,212	$0	$0	$0	$0	$0	$0	$0	$0	$0
26	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Figure 18: From/To Chart of Loan Amounts Pertaining to Client Committees that Moved to another Office

Figure 18 shows the loan amounts that left one office and entered another, hence the From/To concept. The bold numbers on the left represent the *From* offices and the bold numbers on the top represent the *To* offices. The table can be read as follows: $35,995 total of loan amount left office 2 and entered office 3. The cells highlighted in yellow show the amount of committees that moved from the respective office in the left and entered the respective office in the top row. Table 5 summarizes the From/To Chart in Figure 18.

Table 5: Summary of From/To Chart of Loan Amounts Pertaining to Client Committees that Moved to another Office

	Loan Flow Analysis			Current and Future Scenarios			
Office #	Office	From	To	Stayed	Before	After	Difference
2	Asunción	$369,570	$80,492	$162,992	$532,562	$243,484	-$289,079
3	San Lorenzo	$224,473	$338,512	$395,647	$620,121	$734,160	$114,039
4	Caacupé	$70,560	$5,570	$730,909	$801,470	$736,479	-$64,991
5	Carapeguá	$19,097	$49,614	$538,833	$557,929	$588,446	$30,517
6	Luque	$97,287	$45,003	$497,887	$595,174	$542,890	-$52,284
7	Villa Elisa	$160,964	$272,629	$222,984	$383,948	$495,613	$111,665
8	San Ignacio	$0	$0	$251,912	$251,912	$251,912	$0
9	Encarnación	$0	$0	$1,060,692	$1,060,692	$1,060,692	$0
10	Ciudad del Este	$4,870	$0	$696,118	$700,988	$696,118	-$4,870
12	Villa Hayes	$0	$14,277	$45,330	$45,330	$59,607	$14,277
13	Mariano Roque Alonso	$36,988	$112,726	$358,417	$395,406	$471,143	$75,738
14	Caaguazú	$0	$19,704	$909,935	$909,935	$929,639	$19,704
15	Itá	$209,535	$226,281	$527,898	$737,433	$754,179	$16,746
16	Ybycui	$0	$5,678	$137,008	$137,008	$142,686	$5,678
17	Coronel Oviedo	$3,464	$75,320	$323,132	$326,596	$398,452	$71,856
18	Santaní	$85,813	$3,212	$583,370	$669,182	$586,582	-$82,601
19	Paraguarí	$17,542	$53,413	$352,820	$370,362	$406,232	$35,870
20	Lambaré	$184,096	$192,756	$124,169	$308,265	$316,926	$8,660
21	Pilar	$0	$0	$209,551	$209,551	$209,551	$0
22	Villarrica	$15,326	$0	$133,788	$149,114	$133,788	-$15,326
23	Concepción	$0	$4,183	$313,796	$313,796	$317,979	$4,183
24	Villa Ygatimí	$0	$0	$22,225	$22,225	$22,225	$0
25	Curuguaty	$3,212	$0	$124,543	$127,755	$124,543	-$3,212
26	San Pedro	$0	$3,428	$229,853	$229,853	$233,281	$3,428

The calculations for Table 5 were done in the same way as with Table 4. The office that lost the highest loan amount was Asunción ($369,570) which also corresponds to the office that lost the most committees. The office that gained the highest loan amount was San Lorenzo ($338,512) which corresponds to the office that gained the most committees. The office that retained the highest loan amount was Encarnación ($1,060,692). Ten offices did not lose any loans, and eight offices did not gain any loans. The last columns on the right show the impact of the change.

The right-hand side of Table 4 summarizes the *Before* and *After* reassignment scenarios for each office. The *Before* column shows the loan amounts for each office before the reassignment and consists of the sum of the *From* and *Stayed* columns. The *After* column shows the loan amounts for each office after the reassignment, and is a result of the sum of the *To* and *Stayed* columns. The *Difference* column shows whether offices ended up gaining or losing loans and the ones that lost are highlighted in pink.

Summary of Analysis

We analyzed 2,055 client committees which represents around 32,880 individual clients in all of Paraguay, with a loan total of $10,456,607 as shown in

Table 6. The amount of committees that changed was 267, which represents around 4,272 individual clients and 13% of the total amount analyzed. The loan amount that changed was $1,502,798, representing 14% of the total loans analyzed. These, along with other key figures, are summarized in Table 7. If all of the committees were inside their office's geographical limits, the total distance from offices to committees would be reduced by **2,418 miles**.

Table 6: Total Amount of Committees and Loans Analyzed

	Amount of Committees	**Loan Amount**
Total Analyzed	2,055 (approx. 32,880 individual clients)	$10,456,607

Table 7: Summary of Analysis of Reassignment of Client Committees

		From	**To**	**Stayed**
Committees	**Number of Committees**	267 (4,272 individual clients)	267 (4,272 individual clients)	1,788 (28,608 individual clients)
	% of Total Analyzed	13%	13%	87%
	Maximum	52	61	186
	Minimum	1	1	9
	Average	10.68	10.68	71.52
Loans	**Loan Size**	$1,502,798	$1,502,798	$8,953,809
	% of Total Analyzed	14%	14%	86%
	Maximum	$369,570	$338,512	$1,060,692
	Minimum	$3,212	$3,212	$22,225
	Average	$60,112	$60,112	$358,152

Decision Making Tool

After we analyzed the impact of changing committees from one office to another, we created a summary report for each office. An example is shown in Figure 19. Each report serves as a decision making tool as it allows the managers of FP to make decisions on a case by case scenario. Each report includes client information, the loan size, its status (outgoing, incoming, or no change), its distance to the office being reported, and a suggestion. It also includes a summary that counts the number of committees and the loan sizes that are incoming, outgoing, and not changing. It also calculates the before and after

scenarios and its difference. We also included a tool for FP managers to perform a sensitivity analysis. This allows managers to determine a high loan amount to identify valuable clients. Based on that input, the cell on the suggestion column will say *Reconsider*. In Figure 19**Error! Reference source not found.**, the rows of the client committees that meet this criteria are highlighted in yellow.

San Lorenzo Office Executive Summary

	Total Committees	Total Loan Amount
Incoming	61	$ 338,512.33
Outgoing	40	$ 224,473.38
No Change	68	$ 395,647.21
Before	108	$ 620,120.60
After	129	$ 734,159.55
Difference	21	$ 114,038.95

Sensitivity Analysis		
High Loan Amount	$	9,000.00
Maximum Distance		6.59

Client ID	FP ID	Client Name	Loan Amount	Status	Distance to Office (mi)	Suggestion
874336	7558594	VERA RUIZ DIAZ, MARIA BEATRIZ	$ 3,143.76	Incoming	0.31	
4093217	7756568	VILLALBA ROJAS, GRACIELA SOLEDAD	$ 3,783.15	Incoming	4.39	
4025981	7566229	ZALAZAR ESPINOZA, AGRIPINA	$ 2,971.78	Incoming	4.53	
5536953	7779072	ACHAR CHAPARRO, LISANDRI AMADA	$ 12,134.98	Outgoing	7.56	Reconsider
1723399	7651977	ADORNO MOREL, CARMEN MIGUELA	$ 10,527.66	Outgoing	9.49	Reconsider
430945	7527424	ARANDA DE CANTERO, EDITH ROGELIA	$ 3,331.28	Outgoing	10.51	
3221848	7617295	BARRETO LOPEZ, CARMEN	$ 12,531.41	Outgoing	9.95	Reconsider
2237802	7636094	BENITEZ FLECHA, FELICIANA	$ 1,000.33	Outgoing	10.87	
1539460	7766774	BUSTTO DE MARTINEZ, MARIA STELA	$ 2,584.82	Outgoing	5.16	
4218626	7763352	CENTURION GIMENEZ, NOELIA SUSANA	$ 2,965.22	Outgoing	2.66	
1949323	7795324	CORRALES DE DUPUY, EUGENIA	$ 2,752.49	Outgoing	9.74	
4985129	7787377	DUARTE ALMADA, VERONICA LUCIA	$ 4,357.77	Outgoing	5.73	
4506999	7597855	ESPINOLA GONZALEZ, ALBA CECILIA	$ 1,515.21	Outgoing	7.78	
2233944	7568216	ESPINOLA PEREIRA, GLADYS ZUNILDA	$ 16,672.84	Outgoing	5.82	Reconsider
4416778	7774952	FERNANDEZ BOGARIN, ANDREA AVELINA	$ 2,966.04	Outgoing	6.69	

Figure 19: Example of Summary Report of Reassignment of Client Committees for an Office

Implementation Plan

For the implementation of this deliverable, we provided an info packet on how to use the decision making tool and the excel worksheets with the analysis effectively and explained the different areas of the analysis. In our Skype conference call with FP managers we discussed how they should use each tab.

In our step-by-step guide on how to reproduce this analysis, we provided FP with three Excel workbooks: the ray casting workbook, the polygon coordinates workbook, and the analysis workbook. The guide also includes how to use these workbooks in order to use Ray Casting to reassign client committees, use the output of Ray Casting to create a master list of all the client committees and their current and future scenarios, and how to use the master list to reproduce the analysis we made.

Implications

This analysis allows FP managers to make decisions and know which committees they need to change. As stated, if all the committees were inside their offices' geographical limits, the total distance

would be reduced by 2,418 miles. This change could have a huge impact on the organization's transportation costs and could potentially allow them to reach a larger number of client committees. When we traveled to Paraguay, however, we saw that there was resistance to change from asesores and client committees. Asesores do not want their client committees to change because they receive a commission for each committee based on their respective loan amount. Furthermore, asesores develop a relationship of trust with their client committees which they do not wish to lose. As we learned during our visit, many client committees do not wish to have their asesor or office change because they are already used to that asesor and the way they work. For this reason, our decision making tool will allow managers to make more individual decisions in cases where there is more resistance. In terms of changing client committees from one office to another, FP is willing to risk losing client committees as well as asesores that do not want to adapt to the change.

5. Conclusions

The goal of our project was to improve the efficiency of Fundación Paraguaya's Microfinance and Poverty Stoplight Programs by implementing Industrial Engineering techniques. Our project focused on two main challenges: an individual challenge and an organizational challenge. The individual challenge was the lack of efficient planning of meetings by asesores, which we addressed by creating an optimization based scheduling tool that makes the scheduling process for meetings more efficient. The tool groups meetings based on proximity, therefore minimizing the distance asesores travel to their meetings. This tool will be used by 74 asesores in FP on a weekly basis. We calculated the impact of the scheduling tool based on the comparison between ten schedules followed by asesores and the same schedules optimized by our tool. Based on these results, the use of the tool has the potential to decrease the distance traveled by 19.92%. In one office, the distance traveled was reduced by 50.6%.

The organizational challenge was the lack of zoning of FP client committees, which we addressed by modeling the assignment of client committees to offices based on their geographical location and the analyzing the impact of these changes. This analysis will be used by FP managers to determine which client committees they should reassign to other offices to decrease the distance traveled by asesores. If all the reassignments were to be made, the total distance between client committees and offices would be reduced by 2,418 miles. We analyzed 2,055 client committees which represents around 32,880 individual clients in all of Paraguay, with a total loan amount of $10,456,607. The amount of committees that moved from their respective office was 267, which represents around 4,272 individual clients and 13% of the total amount analyzed. The loan amount that moved from one office to another was $1,502,798, representing 14% of the total loans analyzed. In addition we provided FP a report for each office which serves as a decision making tool. This decision making tool allows the managers of FP to make decisions on a case by case scenario. Managers will have to determine a high loan amount and an extra distance they are willing to travel outside of the office's limits for a valuable client in order to reconsider those valuable clients that are being suggested to leave the office based on location.

There are limitations to the solutions we delivered to FP. While our scheduling tool has the advantage of optimally clustering client meetings, in its present version 30 is a realistic limit on the number of client committees that can be scheduled at a single time. Due to the solving time of two minutes we imposed to the model, if 30 clients or more were to be scheduled, the solution may not be optimal. FP asesores, however, do not plan so far ahead and will most likely plan for no more than one week at a time. Another limitation is that the model calculates the distances using Manhattan distance and geographical coordinates, which does not account for roads and traffic conditions. However, we believe this will not affect most of the schedules generated. In terms of the analysis we delivered, a limitation is that the methods we used included a lot of steps which makes it more difficult for FP managers to

reproduce the analysis. Furthermore, if another office's zone were to be added to the analysis, the analysis would have to be done again. Future studies should consider creating a more visual output for the scheduling tool such as connecting it with Google Maps and showing the different groups of meetings. Another idea could be to allow the user to look at the output and decide whether they would prefer putting certain meetings together based on personal preference or client availability and then solve the schedule again.

We recommend FP to start implementing the tool gradually in two to three offices located in the metropolitan area. In this manner, they can gain feedback from the asesores with respect to how the tool improves their efficiency. From there, the tool may be adapted, as necessary, to better meet the needs of asesores. We recommend asesores use the tool to schedule between three and five days and up to twenty clients which makes up a week of work. This will ensure that the solution obtained is optimal. When we traveled to Paraguay, we saw that some asesores did not have Excel in their computers, which is necessary to run the scheduling tool. Administration assured that a way would be provided to grant them access. If this is not possible, asesores can use their managers' computers to create their schedules. We also suggest that FP sets up a remote server with Excel and OpenSolver where asesores can log in to run the scheduling tool. In terms of the analysis of reassignment of client committees, we recommend to use the individual offices' summary reports to make decisions. This will allow them to take a closer look at the clients that are moving from one office to another as well as their loan sizes and distance to the respective office. In this way, they can make a more personalized decision and look out for the interests of both asesores and clients.

We would like to continue developing our scheduling tool by staying in contact with FP managers. Due to the limited timeframe of this MQP, we were not able to see our tool being implemented prior to the project completion. We are interested in seeing how asesores react to the tool and the impact it has on their work. Both of us are interested in doing work beyond our project and use their feedback after they implement it to make the tool better.

6. Reflections

Throughout our project, we faced many challenges that we overcame mostly by showing flexibility to adapt. The challenges include working remotely from a different country, technological barriers with different regional settings, cultural challenges, learning VBA, OpenSolver, and readjusting to different projects. We believe these challenges helped us better prepare for our future careers as well as made us more interested in working for the humanitarian sector.

Working Remotely from a Different Country

Throughout our project, we overcame many obstacles, many of which arose from us and our sponsor being in different countries. Before we began our project, both of us along with one of our advisors Prof. Andrew Trapp, traveled to Asunción, Paraguay to define our project. Even though we had to miss out on a few vacation days, this trip was worth it because we were able to really understand the challenges Fundación Paraguaya was facing and wanted to address with our project. Before we left Paraguay, we had a clear idea of a starting point for our project: the scheduling tool for asesores. After we returned to WPI and started working on our project, we started facing challenges such as not being able to set weekly Skype meetings, not being able to test our tool on their computers with any frequency, and not receiving feedback for continuous improvement. Furthermore, even as we specified that we only had four months to work on our project, the workers at Fundación Paraguaya were not used to the fast-paced working environment at WPI. This slowed our pace from time to time, but we made sure to remain productive and tried to work ahead of time. There was also miscommunication with our liaison mostly during our second deliverable, as we were receiving many different heavy files and had to repeat the same processes over and over with all of them. It took us around a week to be on the same page regarding those files. At the beginning of our project, we struggled to establish the way we could communicate with our liaison. Even though we wanted to have weekly Skype meetings and communicate via email, this was not always the case. To overcome this, we tried different methods to determine the most comfortable mode of communication with Fundación Paraguaya. Eventually, we communicated through WhatsApp, an instant messaging application, and we were able to ask questions and receive answers almost instantly in most cases. Even though this was unconventional, our team had to adapt to advance in our project and ensure open communication.

Technological Barriers with Regional Settings

Another major challenge was the technological barrier and the differences in computer systems. We first built our model in English and all the coding was done in English. When we translated everything to Spanish, we faced more challenges than we had imagined. First, latitude and longitude coordinates varied in their format, as some of them would have periods and some of them would have

commas. Coordinates were essential to our model because we were clustering client committees based on distances between them. This challenge, forced us to give a lot of thought on how we would clean the coordinates and ensure that no matter the format the coordinates were input into our model, we could format them in a uniform way. Another challenge was date filtering. We wanted to include a feature that allowed them to visually filter their client committees by date to suggest the client committees they should meet with. This feature worked perfectly when regional settings were in English, but it did not work when they were in Spanish. We tried many different ways to make it work but in the end decided that it was not a good idea to keep spending so much time on it. Another minor challenge was some formulas in the code for Visual Basic for Applications did not translate to Spanish settings. This was a quick fix but we had already spent so much time troubleshooting for small details related to language settings, that we were discouraged. We, however, were able to overcome all these challenges trying to address these problems from different angles, pulling resources from different places, and knowing when to give up. It also helped that our liaison in Paraguay had experience working with Excel.

Cultural Challenges

We decided to work on this project because both of us wanted to gain experience in using Industrial Engineering methods to solve problems in the humanitarian sector. For this reason, working with Martin Burt's Fundación Paraguaya seemed like a perfect fit for our Major Qualifying Project. In our Reflections Section, we mentioned some of the challenges we encountered during our project, which included the difficulty of working from another country and the challenges related to incorporating into the solutions proposed. These challenges, however, enabled us to gain insight and learn how to solve problems in similar scenarios. Before we went to Paraguay, we had discussed that we were not coming in to solve FP's problems, rather we were going to listen to different FP workers and understand the challenges from their perspectives. Using this mindset, we were able to bring those perspectives into the solution we created.

Learning New Technology: VBA

Another major challenge was learning a computer language from scratch. When we decided we wanted to conduct our MQP using Optimization as the main tool, which we had experience working with, we were not aware we will have to learn a whole new computer language to execute our project. After we went to Paraguay we understood we were not only creating an optimization model to solve a problem but a flexible tool that can accommodate to the number of client committees and days the asesores determine when they use it. Therefore, Visual Basic for Applications (VBA) became relevant in our project. It was definitely a challenge to learn VBA while completing the other parts of the project but with hours of hard work, we were able to grasp the main concepts and functionalities of the language. By the end of the project we were able to write pieces of code without referring to other parts of the code, we understood

the language and its functionalities. We discovered the power of VBA and included userforms in our Excel tool as well as many dynamic macros that ease the use of the tool. Something that was key for our team was that both of the team members learned to use VBA, therefore when one had a problem the other one helped debugging it. This accelerated the process for the VBA portion of the project to be completed.

Learning Rapidly Evolving Technology: OpenSolver

For the development of our optimization tool, we used OpenSolver which is a replacement of Excel's built-in Solver with open-source technology. Excel's Solver allows you to find an optimal maximum or minimum in one cell in Excel subject to constraints that are placed in other cells in Excel. OpenSolver was developed and is currently maintained by Andrew Mason and students at the Engineering Science department of University of Auckland in New Zealand (Mason 2012). OpenSolver keeps being upgraded and problems are regularly posted on the web page and solved on a day-to-day basis. Due to its constant change nature, we had developed our VBA code to use OpenSolver in a version similar to what other projects had used. As mentioned before, many things became problems once we opened the tool in another country including OpenSolver. Through looking on their webpage we found there was a global way to use OpenSolver in VBA. We updated our VBA code to the newest version we found and everything worked perfectly. It is a great advantage that OpenSolver keeps being upgraded but it's a challenge because it requires whoever is using it to keep checking if the problems he encounters are mentioned and solved on the webpage.

Adjusting to a Changing Project Scope

In addition, another challenge we experienced throughout our project was a change of direction in our second project, the redistribution of client committees in new zones. We were planning to use the database of client committees, and using the coordinates of the offices, we were going to determine new zones for each office based on the proximity of client committees and the density of client committees each office had using optimization techniques. Nevertheless, when we started the meetings to discuss this part of the project we were notified that the zones were already determined by Fundación Paraguaya officers and that our task was to assign them to the offices they were going to fall in according to their geographical location and develop and analysis of the impact of these changes. We had to adjust to this new situation and make a plan to determine how we were going to address this new project. We came up with a solution after much thought and we implemented a technique called Ray Casting to assign client committees to offices geographically and then we created a from-to chart analysis to determine the flow of client committees in each office.

Bibliography:

Aggarwal, Charu, and Chandan Reddy. 2013. *Data Clustering: Algorithms and Applications*. CRC Press. http://proquest.safaribooksonline.com/book/software-engineering-and-development/algorithms/9781466558229/chapter-1-an-introduction-to-cluster-analysis/chapter_1_an_introduction_to_c?reader=pf&readerfullscreen=&readerleftmenu=1#X2ludG VybmFsX1BGVmllldz94bWxp.

Alam, Nurul M., and Dr. Mike Getubig. 2010. "Guidelines for Establishing and Operating Grameen Style Microcredit Programs." *Grameen Foundation*. http://www.grameenamerica.org/sites/default/files/Grameen Replication Guidelines.pdf.

Amarilla, Amalia. 2016. "Personal Interview."

Castree, Noel, Rob Kitchin, and Alisdair Rogers. 2013. "Microfinance - Oxford Reference." *Oxford University Press*. http://www.oxfordreference.com/view/10.1093/acref/9780199599868.001.0001/acref-9780199599868-e-1178.

Central Intelligence Agency. 2013. "The World Factbook." *The World Factbook*. https://www.cia.gov/library/publications/the-world-factbook/geos/pa.html.

Fundacion Paraguaya. 2016a. "Fundación Paraguaya | About Us - Fundación Paraguaya." Accessed February 4. http://www.fundacionparaguaya.org.py/?page_id=77.

———. 2016b. "FUNDACIÓN PARAGUAYA | Microfinanzas - FUNDACIÓN PARAGUAYA." Accessed February 13. http://www.fundacionparaguaya.org.py/?page_id=199.

———. 2015. "Informe de Investigación: Trabajo de La Asesora."

Gan, Guojun, Chaoqun Ma, and Jianhong Wu. 2007. *Data Clustering: Theory, Algorithms, and Applications (Vol. 20)*.

Hanratty, Dannin M., and Sandra W. Meditz. 1988. "Paraguay: A Country of Study." *Washington: GPO for the Library of Congress*. http://countrystudies.us/paraguay/2.htm.

Hans Dieter, Seibel. 2003. "History Matters in Microfinance, Working Paper." https://www.econstor.eu/dspace/bitstream/10419/23549/1/2003-5_History_matters.pdf.

Hermes, Niels, and Robert Lensink. 2007. "The Empirics of Microfinance: What Do We Know?" *The Economic Journal* 117 (517): F1–10.

Ledgerwood, Joanna. 2014. *Microfinance Handbook: An Institutional and Financial Perspective*. World Bank Publications.

Likas, Aristidis, Nikos Vlassis, and JakobJ. Verbeek. 2003. "The Global K-Means Clustering Algorithm." *Pattern Recognition* 36: 451–61.

Mason, Andrew. 2012. "OpenSolver – An Open Source Add-in to Solve Linear and Integer Progammes in Excel." In *Operations Research Proceedings*, edited by Diethard Klatte, Hans-Jakob Lathi, and Karl Schmedders, 401–6. Springer Berlin Heidelberg.

Maya, Pablo A. 2012. "Optimisation Models and Algorithms for Non-Profit Logistics and Disaster Management Problems." University of Antwerp.

———. 2013. "Thesis Humanitarian Optimization." *4OR* 11 (4): 397–98.

Mendoza-Abarca, Karla, and Sergey Anokhin. 2013. "Picking Up the Slack: Social Venture, Venture Creation Under Market Failure Conditions (Summary)." *Frontiers of Entrepreneurship Research*. http://digitalknowledge.babson.edu/fer/vol33/iss18/8.

Murray, Sarah. 2010. "Banking for Billions." *Economist Intelligence Unit*. http://www.careinternational.org.uk/linking-for-change/images/banking for billions report.pdf.

National Geographic. 2005. "Paraguay Facts, Paraguay Flag -- National Geographic." *National Geographic Atlas of the World*. http://travel.nationalgeographic.com/travel/countries/paraguay-facts.

Pevcin, Primož. 2012. "Analysis of Cross-Country Differences in the Non-Profit Sector Size." file:///Users/eliaperezluna/Downloads/418.pdf.

Rao, M. R. 1971. "Cluster Analysis and Mathematical Programming." *Journal of the American Statistical Association* 66 (335): 622–26.

Sanabria, Omar. 2016. "Personal Interview."

Sarker, Ruhul A., and Charles S. Newton. 2007. "The Process of Optimization." In *Optimization Modeling A Practical Approach*.

Sengupta, Rajdeep, and P. Aubuchon, Craig. 2008. "The Microfinance Revolution." *Federal Reserve Bank of St. Louis Review* 90.

Siwale, Juliana N., and John Ritchie. 2012. "Disclosing the Loan Officer's Role in Microfinance Development." *International Small Business Journal* 30 (4): 432–50.

Songa, Bander. 2014. "Ray Casting." *Excel Express: Math and Engineering*.

Steele, Paul, Neil Fernando, and Maneka Weddikkara. 2008. *Poverty Reduction That Works: Experience of Scaling Up Development Success*. Earthscan.

Appendix A: Modifications Made to Model (1.1)-(1.6) to Achieve Linearity

1. Replace the Euclidean distance formula $\sqrt{(x^c - x_k)^2 + (y^c - y_k)^2}$ with $|x^c - x_k| + |x^c - x_k|$ for all client committees c and cluster centers k. x^c and y^c refer to given coordinates and x_k and y_k refer to variables that represent cluster center coordinates.

2. Set the constraint of $d_k^c \geq (x_k^{c+} + x_k^{c-} + y_k^{c+} + y_k^{c-}) - M_c * (1 - z_k^c)$ for all x and all k. d_k^c are decision variables that express the distance between point c and center k when assigned, respectively. M_c is a large number, and z_k^c is the variable that states whether a point was assigned to a cluster or not.

3. Substitute $|x^c - x_k| + |x^c - x_k|$ with $x_k^{c+}, x_k^{c-}, y_k^{c+}, y_k^{c-}$ subject to $\ell^c - \ell_k = x_k^{c+} - x_k^{c-}$ and $n^c - n_k = y_k^{c+} - y_k^{c-} \; \forall \, c, \forall \, k$. All, $x_k^{c+}, x_k^{c-}, y_k^{c+}, y_k^{c-}$ are variables.

Appendix B: Visual Basic for Applications Code

Scheduling Tool Model Code

This code enables the tool to create the optimization model that clusters selected meetings based on proximity.

Private Sub Ok_Click()

'Prompts worker with a message if he or she did not specify the number of days

```
If TextBox1.Value = "" Then

    MsgBox ("Necesita determinar el numero de días")

ElseIf IsNumeric(TextBox1) Then

    Sheets("Configuración").Range("C8").Value = TextBox1.Text

End If
```

'Determine the number of selected clients

```
Dim NumClients As Integer

NumClients = Sheets("Configuracion").Cells(10, 3)
```

'Determine the number of clusters

```
Dim NumClusters As Integer

NumClusters = Sheets("Configuracion").Cells(8, 3)
```

'Determine the minimum number of clients assigned per cluster

```
Dim MinClients As Integer

MinClients = Sheets("Configuracion").Cells(4, 3)
```

'Determine the maximum number of clients assigned per cluster

```
Dim MaxClients As Integer

MaxClients = Sheets("Configuracion").Cells(5, 3)
```

'Tests whether the amount of days to plan is too much for the amount of clients selected

If NumClients / NumClusters < MinClients Then

    MsgBox "Reduzca el número permitido de reuniones por día en la pestaña llamada ""Configuración"" o cree el horario para menos días"

 'Tests whether the amount of days to plan is enough for the amount of clients selected

    ElseIf NumClients / NumClusters > MaxClients Then

    MsgBox "Aumente el número permitido de reuniones por día en la pestaña llamada ""Configuración"" o cree el horario para mas días"

    Else

    Unload Me

'Turn off screen updating while performing tasks

    Application.ScreenUpdating = False

'Formulas of "Configuración" tab

    Worksheets("Configuracion").Activate

    Cells(10, 3).Formula = "=Counta(ClientesSeleccionados!" & Range("A:A").Address & ")-1"

    Cells(9, 3).Formula = "=Counta(BaseDeDatos!" & Range("A:A").Address & ")-1"

'Determine value of skip

    Dim skip As Integer

    skip = 1

'Determine the maximum time assigned per cluster

    Dim MaxTime As Integer

    MaxTime = Sheets("Configuracion").Cells(6, 3)

'Determine r as c as integers

    Dim r As Integer

    Dim c As Integer

'Determine the number of clients in the database

```vba
    Dim BaseDeDatos As Integer

    BaseDeDatos = Sheets("Configuracion").Cells(9, 3)

'Lookup coordinates by ID in "BaseDeDatos"

    Worksheets("ClientesSeleccionados").Activate

    For r = 2 To 1 + NumClients

        Cells(r, 2).Formula = "=VLOOKUP(" & Cells(r, 1).Address & ", BaseDeDatos!" & Range(Cells(2,
1), Cells(BaseDeDatos + 1, 4)).Address & ",""2"",FALSE)"

    Next r

    For r = 2 To 1 + NumClients

        Cells(r, 3).Formula = "=VLOOKUP(" & Cells(r, 1).Address & ", BaseDeDatos!" & Range(Cells(2,
1), Cells(BaseDeDatos + 1, 4)).Address & ",""3"",FALSE)"

    Next r

    For r = 2 To 1 + NumClients

        Cells(r, 4).Formula = "=VLOOKUP(" & Cells(r, 1).Address & ", BaseDeDatos!" & Range(Cells(2,
1), Cells(BaseDeDatos + 1, 4)).Address & ",""4"",FALSE)"

    Next r

'Clean coordinates data

    Worksheets("ClientesSeleccionados").Activate

    For r = 2 To 1 + NumClients

        For c = 15 To 16

            Range(Cells(2, 3), Cells(1 + NumClients, 4)).Select

                Selection.Copy

            Cells(2, 13).Select

                Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _

                :=False, Transpose:=False
```

```vba
        Selection.Replace What:=".", Replacement:="", LookAt:=xlPart, _

            SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _

            ReplaceFormat:=False

        Selection.Replace What:=",", Replacement:="", LookAt:=xlPart, _

            SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _

            ReplaceFormat:=False

      Cells(r, c).Formula = "=1*(If(Len(" & Cells(r, c - 2).Address & ")=4,Concatenate(Left(" &
Cells(r, c - 2).Address & ",4),""00""),If(Len(" & Cells(r, c - 2).Address & ")=5,Concatenate(Left(" &
Cells(r, c - 2).Address & ",5),""0""),If(Len(" & Cells(r, c - 2).Address & ")>=6,Left(" & Cells(r, c -
2).Address & ",6),""FALSE""))))"

    Next c

  Next r

'Hide Columns were coordinates are cleaned from ClientesSeleccionados Sheet

Columns("L:P").Select

    Selection.EntireColumn.Hidden = True

'Delete any worksheet in the workbook named "HorarioPreliminar"

  Dim WS2 As Worksheet

  For Each WS2 In Worksheets

    If WS2.Name = "HorarioPreliminar" Then

      Application.DisplayAlerts = False

      Sheets("HorarioPreliminar").Delete

      Application.DisplayAlerts = True

    End If

  Next

'Add new output sheet
```

```
    Sheets.Add.Name = "HorarioPreliminar"

'Add new optimization model sheet

    Sheets.Add.Name = "New_Model"

'Create column with the time for each meeting

    For r = 8 + 2 * (NumClients + skip) To 6 + 3 * (NumClients + skip)

        For c = 6 To 6

            Cells(r, c).Value = Sheets("ClientesSeleccionados").Cells(r - 8 - 2 * NumClients, c - 1)

        Next c

    Next r

'Create Table for Solver Parameters

    Cells(10 + 3 * (NumClients + skip), 2).Value = "passF"

    Cells(10 + 3 * (NumClients + skip), 3).Value = 1000

    Cells(11 + 3 * (NumClients + skip), 2).Value = "preprocess"

    Cells(11 + 3 * (NumClients + skip), 3).Value = "on"

'Create table for binary variables (assignments to each cluster)

    For r = 1 To 1

        Cells(r, 1).Value = 1

    Next r

    For r = 2 To NumClients + 1

        For c = 2 To NumClusters + 1

            Cells(r, c).Value = 0

        Next c

    Next r

'Create table for x+ variable
```

```
    For r = 2 To NumClients + 1

        For c = (2 + NumClusters + skip) To 2 * (NumClusters + skip)

            Cells(r, c).Value = 0

        Next c

    Next r

'Create table for x-variable

    For r = 2 To NumClients + 1

        For c = (2 + (2 * (NumClusters + skip))) To 3 * (NumClusters + skip)

            Cells(r, c).Value = 0

        Next c

    Next r

'Create table for y+ variable

    For r = 2 To NumClients + 1

        For c = (2 + (3 * (NumClusters + skip))) To 4 * (NumClusters + skip)

            Cells(r, c).Value = 0

        Next c

    Next r

'Create table for y- variable

    For r = 2 To NumClients + 1

        For c = (2 + (4 * (NumClusters + skip))) To 5 * (NumClusters + skip)

            Cells(r, c).Value = 0

        Next c

    Next r

'Create table for dpk
```

```
For r = 2 To NumClients + 1

    For c = (2 + (5 * (NumClusters + skip))) To 6 * (NumClusters + skip)

        Cells(r, c).Value = 0

    Next c

Next r

'Create cell for objective value

    For r = 8 + 2 * (NumClients + skip) To 8 + 2 * (NumClients + skip)

        For c = 2 + 2 * (NumClusters + skip) To 2 + 2 * (NumClusters + skip)

            Cells(r, c).Formula = "=sum(" & Cells(r - 6 - 2 * (NumClients + skip), c + 3 * (NumClusters +
skip)).Address & ":" & Cells(r - 9 - NumClients, c - 2 + 4 * (NumClusters + skip)).Address & ")"

        Next c

    Next

'Create cell to insert "0" needed for constraints

    For r = 8 + 2 * (NumClients + skip) To 8 + 2 * (NumClients + skip)

        For c = 3 + 2 * (NumClusters + skip) To 3 + 2 * (NumClusters + skip)

            Cells(r, c).Value = 0

        Next c

    Next r

'Create column for assignment of all constraint (=sum)

    Dim RowShift As Integer

    RowShift = NumClients + 1

    For r = 2 + NumClients + skip To 2 * (NumClients + skip)

        Cells(r, 2).Formula = "=sum(" & Cells(r - RowShift, 2).Address & ":" & Cells(r - RowShift, 1 +
NumClusters).Address & ")"

    Next r
```

'Create column for equal sign of constraint of assigning all

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = 3 To 3

       Cells(r, c).Value = "="

     Next c

   Next r

'Create column for constraint of assigning all(=1)

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = 4 To 4

       Cells(r, c).Value = 1

     Next c

   Next r

'Create table for xc-xk

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = (2 + NumClusters + skip) To 2 * (NumClusters + skip)

       Cells(r, c).Formula = "= (" & Cells(r + 7 + NumClients, 2).Address & "-" & Cells(4 + 2 * (NumClients + skip), c).Address & ")"

     Next c

   Next r

'Create table for x+-x-

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = (2 + (2 * (NumClusters + skip))) To 3 * (NumClusters + skip)

       Cells(r, c).Formula = "=(" & Cells(r - RowShift, c - NumClusters - skip).Address & "-" & Cells(r - RowShift, c).Address & ")"

     Next c

Next r

'Create table for yc-yk

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = (2 + (3 * (NumClusters + skip))) To 4 * (NumClusters + skip)

       Cells(r, c).Formula = "= (" & Cells(r + 7 + NumClients, 3).Address & "-" & Cells(4 + 2 * (NumClients + skip), c - NumClusters - skip).Address & ")"

     Next c

   Next r

'Create table for y+-y-

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = (2 + (4 * (NumClusters + skip))) To 5 * (NumClusters + skip)

       Cells(r, c).Formula = "=(" & Cells(r - RowShift, c - NumClusters - skip).Address & "-" & Cells(r - RowShift, c).Address & ")"

     Next c

   Next r

'Create table for Dpk constraint

   For r = 2 + NumClients + skip To 2 * (NumClients + skip)

     For c = (2 + (5 * (NumClusters + skip))) To 6 * (NumClusters + skip)

       Cells(r, c).Formula = "=((" & Cells(r - RowShift, c - 4 * (NumClusters + skip)).Address & "+" & Cells(r - RowShift, c - 3 * (NumClusters + skip)).Address & "+" & Cells(r - RowShift, c - 2 * (NumClusters + skip)).Address & "+" & Cells(r - RowShift, c - NumClusters - skip).Address & ")-" & Cells(r, 2 + 6 * (NumClusters + skip)).Address & "*(" & Cells(1, 1).Address & "-" & Cells(r - skip - NumClients, c - 5 * (NumClusters + skip)).Address & "))"

     Next c

   Next r

'Create column for Mp constraint

For r = 2 + NumClients + skip To 2 * (NumClients + skip)

    For c = 2 + 6 * (NumClusters + skip) To 2 + 6 * (NumClusters + skip)

       Cells(r, c).Formula = "=max(abs(" & Cells(8 + 2 * (NumClients + skip), 4).Address & "-" & Cells(r + 7 + NumClients, 2).Address & "),abs(" & Cells(9 + 2 * (NumClients + skip), 4).Address & "-" & Cells(r + 7 + NumClients, 2).Address & "))+max(abs(" & Cells(8 + 2 * (NumClients + skip), 5).Address & "-" & Cells(r + 7 + NumClients, 3).Address & "),abs(" & Cells(9 + 2 * (NumClients + skip), 5).Address & "-" & Cells(r + 7 + NumClients, 3).Address & "))"

    Next c

  Next r

'Create table for the sum of meeting time of meetings assigned to each cluster

  For r = 2 + NumClients + skip To 2 * (NumClients + skip)

    For c = 4 + 6 * (NumClusters + skip) To 7 * (NumClusters + skip) + 2

       Cells(r, c).Formula = "=(" & Cells(r + NumClients + 7, 6).Address & "*" & Cells(r - NumClients - skip, c - 2 - 6 * (NumClusters + skip)).Address & ")"

    Next c

  Next r

'Create row for sum of time of all meetings assigned to each cluster

  For r = 2 * (NumClients + skip) + 1 To 2 * (NumClients + skip) + 1

    For c = 4 + 6 * (NumClusters + skip) To 7 * (NumClusters + skip) + 2

       Cells(r, c).Formula = "=sum(" & Cells(2 + NumClients + skip, c).Address & ":" & Cells(2 * (NumClients + skip), c).Address & ")"

    Next c

  Next r

'Create row for "<=" for the upper bound on time per cluster

  For r = 2 * (NumClients + skip) + 2 * (skip) To 2 * (NumClients + skip) + 2 * (skip)

    For c = 4 + 6 * (NumClusters + skip) To 7 * (NumClusters + skip) + 2

```
            Cells(r, c).Value = "<="

        Next c

    Next r

'Create row for upper bound on time per cluster

    For r = 2 * (NumClients + skip) + 3 * (skip) To 2 * (NumClients + skip) + 3 * (skip)

        For c = 4 + 6 * (NumClusters + skip) To 7 * (NumClusters + skip) + 2

            Cells(r, c).Value = MaxTime

        Next c

    Next r

'Create row for lower bound of meetings per cluster

    For r = 2 + 2 * (NumClients + skip) To 2 + 2 * (NumClients + skip)

        For c = 2 To NumClusters + 1

            Cells(r, c).Value = MinClients

        Next c

    Next r

'Create row for "<=" for bounds on meetings per cluster

    For r = 2 + 2 * (NumClients + skip) + (skip) To 2 + 2 * (NumClients + skip) + (skip)

        For c = 2 To NumClusters + 1

            Cells(r, c).Value = "<="

        Next c

    Next r

'Create row for sum of meetings per cluster

    For r = 2 + 2 * (NumClients + skip) + 2 * (skip) To 2 + 2 * (NumClients + skip) + 2 * (skip)

        For c = 2 To NumClusters + 1
```

```vba
        Cells(r, c).Formula = "=sum(" & Cells(2, c).Address & ":" & Cells(1 + NumClients, c).Address &
")"

    Next c

  Next r

'Create row for "<=" for bounds on meetings per cluster

  For r = 2 + 2 * (NumClients + skip) + 3 * (skip) To 2 + 2 * (NumClients + skip) + 3 * (skip)

    For c = 2 To NumClusters + 1

      Cells(r, c).Value = "<="

    Next c

  Next r

'Create row for upper bound of meetings per cluster

  For r = 2 + 2 * (NumClients + skip) + 4 * (skip) To 2 + 2 * (NumClients + skip) + 4 * (skip)

    For c = 2 To NumClusters + 1

      Cells(r, c).Value = MaxClients

    Next c

  Next r

'Create table for latitudes and longitudes (x and y coordinates) of selected clients

  For r = 8 + 2 * (NumClients + skip) To 6 + 3 * (NumClients + skip)

    For c = 2 To 3

      Cells(r, c).Value = Sheets("ClientesSeleccionados").Cells(r - 8 - 2 * NumClients, c + 13)

    Next c

  Next r

'Create cell for the minimum out of the x coordinates with formula

  Cells(8 + 2 * (NumClients + skip), 4).Formula = "=min(" & Cells(8 + 2 * (NumClients + skip),
2).Address & ":" & Cells(6 + 3 * (NumClients + skip), 2).Address & ")"
```

'Create cell for the maximum out of the x coordinates with formula

    Cells(9 + 2 * (NumClients + skip), 4).Formula = "=max(" & Cells(8 + 2 * (NumClients + skip), 2).Address & ":" & Cells(7 + 3 * (NumClients + skip), 2).Address & ")"

'Create cell for the minimum out of the y coordinates with formula

    Cells(8 + 2 * (NumClients + skip), 5).Formula = "=min(" & Cells(8 + 2 * (NumClients + skip), 3).Address & ":" & Cells(6 + 3 * (NumClients + skip), 3).Address & ")"

'Create cell for the maximum out of the y coordinates with formula

    Cells(9 + 2 * (NumClients + skip), 5).Formula = "=max(" & Cells(8 + 2 * (NumClients + skip), 3).Address & ":" & Cells(7 + 3 * (NumClients + skip), 3).Address & ")"

'Create row for x centers variable lower bound

    For r = 2 + 2 * (NumClients + skip) To 2 + 2 * (NumClients + skip)

        For c = 2 + NumClusters + skip To 2 * (NumClusters + skip)

            Cells(r, c).Value = Cells(8 + 2 * (NumClients + skip), 4)

        Next c

    Next r

'Create row for "<=" from lower bounds --> x Centers

    For r = 3 + 2 * (NumClients + skip) To 3 + 2 * (NumClients + skip)

        For c = 2 + NumClusters + skip To 2 * (NumClusters + skip)

            Cells(r, c).Value = "<="

        Next c

    Next r

'Create row for x centers changing variable

    For r = 4 + 2 * (NumClients + skip) To 4 + 2 * (NumClients + skip)

        For c = 2 + NumClusters + skip To 2 * (NumClusters + skip)

            Cells(r, c).Value = 0

```
        Next c

    Next r

'Create row for "<=" from x centers--> upper bounds

    For r = 5 + 2 * (NumClients + skip) To 5 + 2 * (NumClients + skip)

        For c = 2 + NumClusters + skip To 2 * (NumClusters + skip)

            Cells(r, c).Value = "<="

        Next c

    Next r

'Create row for x centers variable upper bound

    For r = 6 + 2 * (NumClients + skip) To 6 + 2 * (NumClients + skip)

        For c = 2 + NumClusters + skip To 2 * (NumClusters + skip)

            Cells(r, c).Value = Cells(9 + 2 * (NumClients + skip), 4)

        Next c

    Next r

'Create row for y centers variable lower bound

    For r = 2 + 2 * (NumClients + skip) To 2 + 2 * (NumClients + skip)

        For c = 2 + 2 * (NumClusters + skip) To 3 * (NumClusters + skip)

            Cells(r, c).Value = Cells(8 + 2 * (NumClients + skip), 5)

        Next c

    Next r

'Create row for "<=" from lower bounds --> y centers

    For r = 3 + 2 * (NumClients + skip) To 3 + 2 * (NumClients + skip)

        For c = 2 + 2 * (NumClusters + skip) To 3 * (NumClusters + skip)

            Cells(r, c).Value = "<="
```

Next c

Next r

'Create row for y centers changing variable

For r = 4 + 2 * (NumClients + skip) To 4 + 2 * (NumClients + skip)

For c = 2 + 2 * (NumClusters + skip) To 3 * (NumClusters + skip)

Cells(r, c).Value = 0

Next c

Next r

'Create row for "<=" from y centers--> upper bounds

For r = 5 + 2 * (NumClients + skip) To 5 + 2 * (NumClients + skip)

For c = 2 + 2 * (NumClusters + skip) To 3 * (NumClusters + skip)

Cells(r, c).Value = "<="

Next c

Next r

'Create row for y centers variable upper bound

For r = 6 + 2 * (NumClients + skip) To 6 + 2 * (NumClients + skip)

For c = 2 + 2 * (NumClusters + skip) To 3 * (NumClusters + skip)

Cells(r, c).Value = Cells(9 + 2 * (NumClients + skip), 5)

Next c

Next r

'Begin creating the optimization model for the Scheduling Tool

OpenSolver.ResetModel Sheet:=Sheets("New_Model")

'Set Objective Function

OpenSolver.SetObjectiveFunctionCell Sheets("New_Model").Range(Cells(8 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(8 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

OpenSolver.SetObjectiveSense MinimiseObjective, Sheet:=Sheets("New_Model")

'Variable Definition

OpenSolver.SetDecisionVariables Union(Sheets("New_Model").Range(Cells(2, 2), Cells(NumClients + 1, NumClusters + 1)), Sheets("New_Model").Range(Cells(2, (2 + NumClusters + skip)), Cells(NumClients + 1, 2 * (NumClusters + skip))), Sheets("New_Model").Range(Cells(2, 2 + 2 * (NumClusters + skip)), Cells(NumClients + 1, 3 * (NumClusters + skip))), Sheets("New_Model").Range(Cells(2, 2 + 3 * (NumClusters + skip)), Cells(NumClients + 1, 4 * (NumClusters + skip))), Range(Cells(2, 2 + 4 * (NumClusters + skip)), Cells(NumClients + 1, 5 * (NumClusters + skip))), Sheets("New_Model").Range(Cells(2, 2 + 5 * (NumClusters + skip)), Cells(NumClients + 1, 6 * (NumClusters + skip))), Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + NumClusters + skip), Cells(4 + 2 * (NumClients + skip), 2 * (NumClusters + skip))), Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(4 + 2 * (NumClients + skip), 3 * (NumClusters + skip)))), Sheet:=Sheets("New_Model")

'Constraint Binary Variables Assignment

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2), Cells(NumClients + 1, NumClusters + 1)), RelationBIN, Sheet:=Sheets("New_Model")

'Constraint all points (clients) need to be assigned

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2), Cells(2 * (NumClients + skip), 2)), RelationEQ, Sheets("New_Model").Range(Cells(2 + NumClients + skip, 4), Cells(2 * (NumClients + skip), 4)), Sheet:=Sheets("New_Model")

'Constraint lower bound (amount of meetings per clusters)

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + 2 * (NumClients + skip), 2), Cells(2 + 2 * (NumClients + skip), NumClusters + skip)), RelationLE, Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2), Cells(4 + 2 * (NumClients + skip), NumClusters + skip)), Sheet:=Sheets("New_Model")

'Constraint upper bound (amount of meetings per clusters

'OpenSolver.AddConstraint   New_Model.Range(),   RelationLE,   New_Model.Range(), Sheet:=New_Model

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2), Cells(4 + 2 * (NumClients + skip), NumClusters + skip)), RelationLE, Sheets("New_Model").Range(Cells(6 + 2 * (NumClients + skip), 2), Cells(6 + 2 * (NumClients + skip), NumClusters + skip)), Sheet:=Sheets("New_Model")

'Constraint xp-xk=x+-x-

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2 + (NumClusters + skip)), Cells(2 * (NumClients + skip), 2 * (NumClusters + skip))), RelationEQ, Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2 + 2 * (NumClusters + skip)), Cells(2 * (NumClients + skip), 3 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Costraint yp-yk=y+-y-

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2 + 3 * (NumClusters + skip)), Cells(2 * (NumClients + skip), 4 * (NumClusters + skip))), RelationEQ, Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2 + 4 * (NumClusters + skip)), Cells(2 * (NumClients + skip), 5 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint Dpk >= Dpk constraint

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + 5 * (NumClusters + skip)), Cells(NumClients + 1, 6 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Range(Cells(2 + NumClients + skip, 2 + 5 * (NumClusters + skip)), Cells(2 * (NumClients + skip), 6 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint lower bound of centers (x coordinate)

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + 2 * (NumClients + skip), 2 + NumClusters + skip), Cells(2 + 2 * (NumClients + skip), 2 * (NumClusters + skip))), RelationLE, Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + NumClusters + skip), Cells(4 + 2 * (NumClients + skip), 2 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint upper bound of centers (x coordinate)

OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + NumClusters + skip), Cells(4 + 2 * (NumClients + skip), 2 * (NumClusters + skip))), RelationLE,

Sheets("New_Model").Range(Cells(6 + 2 * (NumClients + skip), 2 + NumClusters + skip), Cells(6 + 2 * (NumClients + skip), 2 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint lower bound of centers (y coordinate)

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(2 + 2 * (NumClients + skip), 3 * (NumClusters + skip))), RelationLE, Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(4 + 2 * (NumClients + skip), 3 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint upper bound of centers (y coordinate)

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(4 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(4 + 2 * (NumClients + skip), 3 * (NumClusters + skip))), RelationLE, Sheets("New_Model").Range(Cells(6 + 2 * (NumClients + skip), 2 + 2 * (NumClusters + skip)), Cells(6 + 2 * (NumClients + skip), 3 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint upper bound of meeting time per cluster

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(1 + 2 * (NumClients + skip), 4 + 6 * (NumClusters + skip)), Cells(1 + 2 * (NumClients + skip), 2 + 7 * (NumClusters + skip))), RelationLE, Sheets("New_Model").Range(Cells(3 + 2 * (NumClients + skip), 4 + 6 * (NumClusters + skip)), Cells(3 + 2 * (NumClients + skip), 2 + 7 * (NumClusters + skip))), Sheet:=Sheets("New_Model")

'Constraint for x+, x-, y+, y- nonnegative numbers

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + NumClusters + skip), Cells(1 + NumClients, 2 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Cells(8 + 2 * (NumClients + skip), 3 + 2 * (NumClusters + skip)), Sheet:=Sheets("New_Model")

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + 2 * (NumClusters + skip)), Cells(1 + NumClients, 3 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Cells(8 + 2 * (NumClients + skip), 3 + 2 * (NumClusters + skip)), Sheet:=Sheets("New_Model")

   OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + 3 * (NumClusters + skip)), Cells(1 + NumClients, 4 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Cells(8 + 2 * (NumClients + skip), 3 + 2 * (NumClusters + skip)), Sheet:=Sheets("New_Model")

```vba
    OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + 4 * (NumClusters + skip)), Cells(1 + NumClients, 5 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Cells(8 + 2 * (NumClients + skip), 3 + 2 * (NumClusters + skip)), Sheet:=Sheets("New_Model")

    OpenSolver.AddConstraint Sheets("New_Model").Range(Cells(2, 2 + 5 * (NumClusters + skip)), Cells(1 + NumClients, 6 * (NumClusters + skip))), RelationGE, Sheets("New_Model").Cells(8 + 2 * (NumClients + skip), 3 + 2 * (NumClusters + skip)), Sheet:=Sheets("New_Model")

    OpenSolver.SetNonNegativity False, Sheet:=Sheets("New_Model")

    OpenSolver.SetMaxTime 120, Sheet:=Sheets("New_Model")

    OpenSolver.SetSolverParameters "CBC", Sheets("New_Model").Range(Cells(10 + 3 * (NumClients + skip), 2), Cells(11 + 3 * (NumClients + skip), 3)), Sheet:=Sheets("New_Model")

    Dim Result As OpenSolverResult

    Result = RunOpenSolver(False, True)

    If Result = ErrorOccurred Or Result = Infeasible Then

        MsgBox "El horario no pudo ser creado. Revise los clientes seleccionados y la cantidad de días seleccionados. Si el error prevalece, contacte a su supervisor"

'Delete any worksheet in the workbook named "New_Model"

  Dim WS3 As Worksheet

  For Each WS3 In Worksheets

    If WS3.Name = "New_Model" Then

      Application.DisplayAlerts = False

      Sheets("New_Model").Delete

      Application.DisplayAlerts = True

    End If

  Next

  End

    End If
```

72

'Insert names of clients in model sheet next to aassignment table (binary variables)

    For r = 2 To 1 + NumClients

      For c = 1 To 1

        Cells(r, c).Value = Sheets("ClientesSeleccionados").Cells(r, c + 1)

      Next c

    Next r

'Change font of worksheets

    Sheets("ClientesSeleccionados").Activate

      Range(Cells(2, 1), Cells(1 + NumClients, 1000)).Select

      With Selection.Font

        .Name = "Times New Roman"

        .FontStyle = "Regular"

        .Size = 12

      End With

    Sheets("BaseDeDatos").Activate

      Range(Cells(2, 1), Cells(1 + BaseDeDatos, 1000)).Select

      With Selection.Font

        .Name = "Times New Roman"

        .FontStyle = "Regular"

        .Size = 10

      End With

'Create assignment table in preliminary schedule (HorarioPreliminar) sheet including cluster and the names of the clients assigned to that cluster

    Dim Counter As Integer

```vba
Counter = 1

For c = 2 To 1 + NumClusters

  For r = 3 To 2 + NumClients

    Sheets("HorarioPreliminar").Activate

      Cells(2, c).Value = "Día" & " " & (c - 1)

    Sheets("New_Model").Activate

    If Cells(r - 1, c).Value = "1" Then

      Sheets("HorarioPreliminar").Activate

        Cells(2 + Counter, c).Value = Sheets("New_Model").Cells(r - 1, 1).Value

         Cells(2 + Counter, c).Select

          Selection.Borders(xlDiagonalDown).LineStyle = xlNone

          Selection.Borders(xlDiagonalUp).LineStyle = xlNone

          With Selection.Borders(xlEdgeLeft)

            .LineStyle = xlContinuous

            .ColorIndex = 0

            .TintAndShade = 0

            .Weight = xlThin

          End With

          With Selection.Borders(xlEdgeTop)

            .LineStyle = xlContinuous

            .ColorIndex = 0

            .TintAndShade = 0

            .Weight = xlThin

          End With
```

```vba
With Selection.Borders(xlEdgeBottom)

    .LineStyle = xlContinuous

    .ColorIndex = 0

    .TintAndShade = 0

    .Weight = xlThin

End With

With Selection.Borders(xlEdgeRight)

    .LineStyle = xlContinuous

    .ColorIndex = 0

    .TintAndShade = 0

    .Weight = xlThin

End With

With Selection.Borders(xlInsideVertical)

    .LineStyle = xlContinuous

    .ColorIndex = 0

    .TintAndShade = 0

    .Weight = xlThin

End With

With Selection.Borders(xlInsideHorizontal)

    .LineStyle = xlContinuous

    .ColorIndex = 0

    .TintAndShade = 0

    .Weight = xlThin

End With
```

```
            Counter = Counter + 1

        End If

      Next r

      Counter = 1

  Next c

'Format for Preliminary Schedule (Horario Preliminar) Sheet including headings for client assignment
table

  Sheets("HorarioPreliminar").Activate

    For c = 2 To 1 + NumClusters

      Cells(2, c).Select

        With Selection.Interior

          .Pattern = xlSolid

          .PatternColorIndex = xlAutomatic

          .Color = 32768

        End With

        With Selection.Font

          .ThemeColor = xlThemeColorDark1

        End With

        Selection.Font.Size = 14

        Selection.Font.Bold = True

      Worksheets("HorarioPreliminar").Cells.EntireColumn.AutoFit

    Next c

    ActiveWindow.DisplayGridlines = False

'Activate Cell A2
```

```vba
    Sheets("ClientesSeleccionados").Activate

        Range("A2").Select

    Worksheets("Configuracion").Activate

        Range("A1").Select

    Worksheets("BaseDeDatos").Activate

        Range("A2").Select

    Sheets("HorarioPreliminar").Activate

        Range("B3").Activate

'Delete any worksheet in the workbook named "New_Model"

    Dim WS4 As Worksheet

    For Each WS4 In Worksheets

        If WS4.Name = "New_Model" Then

            Application.DisplayAlerts = False

            Sheets("New_Model").Delete

            Application.DisplayAlerts = True

        End If

    Next

End If

End Sub
```

Code that Checks for Errors Before Creating the Model

This code checks for errors in the input of the model. The types of errors are summarized in Table 2.

```vba
Sub Solver_Model()

'Turn off screen updating while performing tasks

    Application.ScreenUpdating = False
```

'Insert formulas for NumClients (Number of clients selected) and NumTiempo (Clients *for which*
asesores specified duration of meetings)

    Worksheets("Configuracion").Activate

        Cells(10, 3).Formula = "=Counta(ClientesSeleccionados!" & Range("A:A").Address & ")-1"

        Cells(11, 3).Formula = "=Counta(ClientesSeleccionados!" & Range("E:E").Address & ")-1"

'Determine NumClients

    Dim NumClients As Integer

    NumClients = Sheets("Configuracion").Cells(10, 3)

'Determine NumTiempo

    Dim NumTiempo As Integer

    NumTiempo = Sheets("Configuracion").Cells(11, 3)

'Apply conditional formatting to first column of clientes seleccionados to show the duplicates in the
selected clients

    Worksheets("ClientesSeleccionados").Activate

        Range(Cells(2, 1), Cells(NumClients + 1, 1)).Select

            Selection.FormatConditions.AddUniqueValues

            Selection.FormatConditions(Selection.FormatConditions.Count).SetFirstPriority

            Selection.FormatConditions(1).DupeUnique = xlDuplicate

            With Selection.FormatConditions(1).Font

                .Color = -16383844

                .TintAndShade = 0

            End With

            With Selection.FormatConditions(1).Interior

                .PatternColorIndex = xlAutomatic

                .Color = 13551615

```vba
        .TintAndShade = 0

    End With

    Selection.FormatConditions(1).StopIfTrue = False

'Checks for duplicates in another tab called "CheckDuplicates" by copying and pasting into the new tab,
removing duplicates in that list, and comparing the amount of rows

  Sheets("ClientesSeleccionados").Activate

    Range(Cells(2, 1), Cells(1 + NumClients, 1)).Select

      Selection.Copy

  Sheets.Add.Name = "CheckDuplicates"

  Sheets("CheckDuplicates").Activate

    Range("A1").PasteSpecial

  Columns("A:A").Select

    Application.CutCopyMode = False

    ActiveSheet.Columns("A:A").RemoveDuplicates Columns:=1, Header:=xlNo

  Sheets("Configuración").Activate

    Cells(12, 3).Formula = "=Counta(CheckDuplicates!" & Range("A:A").Address & ")"

'Determine Duplicates

  Dim Duplicates As Integer

  Duplicates = Sheets("Configuracion").Cells(12, 3)

'If Statement to check if the number of clients with duplicates removed is less than the number in
"ClientesSeleccionados" tab

  If Duplicates < NumClients Then

'Delete Worksheet called "CheckDuplicates" and showing message box for eliminating duplicates

    Dim WS4 As Worksheet

      For Each WS4 In Worksheets
```

```vba
        If WS4.Name = "CheckDuplicates" Then

            Application.DisplayAlerts = False

            Sheets("CheckDuplicates").Delete

            Application.DisplayAlerts = True

        End If

    Next

    Worksheets("ClientesSeleccionados").Activate

    MsgBox "Hay clientes repetidos. Elimine uno de los repetidos resaltados en rojo"

ElseIf NumTiempo < NumClients Then

'Delete Worksheet called "CheckDuplicates" and show message box for inserting meeting time for all
selected clients

    Dim WS5 As Worksheet

        For Each WS5 In Worksheets

            If WS5.Name = "CheckDuplicates" Then

                Application.DisplayAlerts = False

                Sheets("CheckDuplicates").Delete

                Application.DisplayAlerts = True

            End If

        Next

    Worksheets("ClientesSeleccionados").Activate

    MsgBox "Inserte tiempo de duracion de reunion para todos los clientes seleccionados"

Else

'Delete Worksheet called "CheckDuplicates"

    Dim WS6 As Worksheet
```

```vba
    For Each WS6 In Worksheets

        If WS6.Name = "CheckDuplicates" Then

            Application.DisplayAlerts = False

            Sheets("CheckDuplicates").Delete

            Application.DisplayAlerts = True

        End If

    Next

'Remove conditional formatting

    Worksheets("ClientesSeleccionados").Activate

        Range("A:A").FormatConditions.Delete

        Range("A2").Select

'Show userform that asks for the number of days to schedule. See Inserte User form for the code of the
rest of the tool

    Inserte.Show

  End If

End Sub
```

Macros Used by the Tool

This code was used for the user forms included in the excel tool. These are shown in Figure 11.

```vba
Sub Abrir()

  Inserte.Show

End Sub

Sub Minimo()

  EditarMinimo.Show

End Sub

Sub Maximo()
```

```vba
    EditarMaximo.Show

End Sub

Sub MaxTiempo()

    EditarMaxTiempo.Show

End Sub

Sub Show_UserForm()

    Lista.Show

End Sub

Sub Nombres()

'Turn off screen updating while performing tasks

    Application.ScreenUpdating = False

 'Activate "Configuracion" tab

    Worksheets("Configuracion").Activate

'Insert formulas to count the number of selected clients in "Clientes Seleccionados" and number of clients
in Base De Datos

    Cells(10, 3).Formula = "=Counta(ClientesSeleccionados!" & Range("A:A").Address & ")-1"

    Cells(9, 3).Formula = "=Counta(BaseDeDatos!" & Range("A:A").Address & ")-1"

'Determine NumClients and BasDeDatos

    Dim NumClients As Integer

    NumClients = Sheets("Configuracion").Cells(10, 3)

    Dim BaseDeDatos As Integer

    BaseDeDatos = Sheets("Configuracion").Cells(9, 3)

'Check if an ID number is not in BaseDeDatos and return message

    Worksheets("ClientesSeleccionados").Activate
```

```vba
For r = 2 To 1 + NumClients

    Cells(r, 2).Formula = "=VLOOKUP(" & Cells(r, 1).Address & ", BaseDeDatos!" & Range(Cells(2, 1), Cells(BaseDeDatos + 1, 4)).Address & ",""2"",FALSE)"

    If IsError(Cells(r, 2)) Then

        MsgBox "Una de las cedulas de identidad en la columna A no se encuentra en la base de datos. Revise si la cedula de identidad esta correcta o agrege la informacion del cliente a la base de datos."

    End If

Next r
'Font for Clientes Seleccionados

  Sheets("ClientesSeleccionados").Activate

    Range(Cells(2, 1), Cells(1 + NumClients, 1000)).Select

    With Selection.Font

      .Name = "Times New Roman"

      .FontStyle = "Regular"

      .Size = 12

    End With

  Sheets("BaseDeDatos").Activate

    Range(Cells(2, 1), Cells(1 + BaseDeDatos, 1000)).Select

    With Selection.Font

      .Name = "Times New Roman"

      .FontStyle = "Regular"

      .Size = 10

    End With

'Activate Cells "A2" in "Clientes Seleccionados" and "BaseDeDatos"

  Worksheets("BaseDeDatos").Activate
```

```vba
    Range("A2").Select

    Sheets("ClientesSeleccionados").Activate

        Range("A2").Select

End Sub

Sub Reiniciar()

'Turn off screen updating while performing tasks

    Application.ScreenUpdating = False

'Activate Worksheet and select columns "A:E"

    Worksheets("ClientesSeleccionados").Activate

        Range("A2:E2").Select

        Range(Selection, Selection.End(xlToRight)).Select

        Range(Selection, Selection.End(xlDown)).Select

            Selection.ClearContents

        Range("A2").Select

    Worksheets("BaseDeDatos").Activate

        Range("A2").Select

    Worksheets("ClientesSeleccionados").Activate

End Sub
```

Code Used in all Userforms

Userform Used to Determine the Maximum Amount of Meetings per Day

```vba
Private Sub OkMaximo_Click()

    Worksheets("Configuracion").Unprotect

    Application.ScreenUpdating = False

    If TextBox1.Value = "" Then
```

MsgBox ("Necesita determinar el numero de dias")

ElseIf IsNumeric(TextBox1) Then

Worksheets("Configuracion").Range("C5").Value = TextBox1.Text

End If

Cells.Select

Selection.Locked = True

Selection.FormulaHidden = True

ActiveSheet.Protect

Worksheets("Configuracion").Protect

Worksheets("Configuracion").Activate

Range("C4").Select

Unload Me

End Sub

Private Sub TextBox1_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)

If (KeyAscii > 47 And KeyAscii < 58) Then

KeyAscii = KeyAscii

Else

KeyAscii = 0

MsgBox "Solo puede insertar numeros"

End If

End Sub

Private Sub UserForm_Initialize()

Application.ScreenUpdating = False

With EditarMaximo

```vba
    .StartUpPosition = 0

    .Top = 200

    .Left = 375

  End With

  Application.ScreenUpdating = True

End Sub

Private Sub OkMaxTiempo_Click()

  Worksheets("Configuracion").Unprotect

  Application.ScreenUpdating = False

  If TextBox1.Value = "" Then

    MsgBox ("Necesita determinar el numero de dias")

  ElseIf IsNumeric(TextBox1) Then

    Worksheets("Configuracion").Range("C6").Value = TextBox1.Text

  End If

  Cells.Select

  Selection.Locked = True

  Selection.FormulaHidden = True

  ActiveSheet.Protect

  Worksheets("Configuracion").Protect

  Worksheets("Configuracion").Activate

  Range("C4").Select

  Unload Me

End Sub

Private Sub TextBox1_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)
```

```vba
If (KeyAscii > 47 And KeyAscii < 58) Then

    KeyAscii = KeyAscii

Else

    KeyAscii = 0

    MsgBox "Solo puede insertar numeros"

End If

End Sub
```

Userform Used to Determine the Maximum Total Meeting Time per Day

```vba
Private Sub OkMaxTiempo_Click()

    Worksheets("Configuracion").Unprotect

    Application.ScreenUpdating = False

    If TextBox1.Value = "" Then

        MsgBox ("Necesita determinar el numero de dias")

    ElseIf IsNumeric(TextBox1) Then

        Worksheets("Configuracion").Range("C6").Value = TextBox1.Text

    End If

    Cells.Select

    Selection.Locked = True

    Selection.FormulaHidden = True

    ActiveSheet.Protect

    Worksheets("Configuracion").Protect

    Worksheets("Configuracion").Activate

    Range("C4").Select

    Unload Me
```

```
End Sub

Private Sub TextBox1_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)

    If (KeyAscii > 47 And KeyAscii < 58) Then

        KeyAscii = KeyAscii

    Else

        KeyAscii = 0

        MsgBox "Solo puede insertar numeros"

    End If

End Sub

Private Sub UserForm_Initialize()

    Application.ScreenUpdating = False

    With EditarMaxTiempo

        .StartUpPosition = 0

        .Top = 200

        .Left = 375

    End With

    Application.ScreenUpdating = True

End Sub
```

Userform Used to Determine the Minimum Amount of Meetings per Day

```
Private Sub OkMinimo_Click()

    Worksheets("Configuracion").Unprotect

    Application.ScreenUpdating = False

    If TextBox1.Value = "" Then

        MsgBox ("Necesita determinar el numero de dias")
```

```vba
   ElseIf IsNumeric(TextBox1) Then

      Worksheets("Configuracion").Range("C4").Value = TextBox1.Text

   End If

   Cells.Select

   Selection.Locked = True

   Selection.FormulaHidden = True

   ActiveSheet.Protect

   Worksheets("Configuracion").Protect

   Worksheets("Configuracion").Activate

   Range("C4").Select

   Unload Me

End Sub

Private Sub TextBox1_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)

   If (KeyAscii > 47 And KeyAscii < 58) Then

      KeyAscii = KeyAscii

   Else

      KeyAscii = 0

      MsgBox "Solo puede insertar numeros"

   End If

End Sub

Private Sub UserForm_Initialize()

   Application.ScreenUpdating = False

   With EditarMinimo

      .StartUpPosition = 0
```

```
        .Top = 200

        .Left = 375

    End With

    Application.ScreenUpdating = True

End Sub

Private Sub Agregar_Click()

'Determine BaseDeDatos and LastRow

    Dim BaseDeDatos As Integer

    BaseDeDatos = Sheets("Configuracion").Cells(9, 3)

    Dim LastRow As Object

'Checks whether the worker filled out both fields were filled out

    If Cedula.Value = "" Or Tiempo.Value = "" Then

        MsgBox ("Necesita llenar informacion para ambos")

    End If

'Checks wether the ID of the client inserted exists in the database

    Set LastRow = Worksheets("ClientesSeleccionados").Range("a65536").End(xlUp)

    LastRow.Offset(1, 0).Value = Cedula.Text

    LastRow.Offset(1, 4).Value = Tiempo.Text

    LastRow.Offset(1, 1).Formula = "=IfError(VLOOKUP(" & LastRow.Offset(1, 0).Address & ",
BaseDeDatos!" & Range(Cells(2, 1), Cells(BaseDeDatos + 1, 4)).Address & ",""2"",FALSE),""No Existe
Cliente"")"

    If LastRow.Offset(1, 1).Value = "No Existe Cliente" Then

        MsgBox "La cedula de identidad que agrego no se encuentra en la base de datos. Revise si esta
correcta o agrege la informacion del cliente a la base de datos."

        LastRow.Offset(1, 1).Select
```

```vba
        Selection.FormatConditions.Add Type:=xlTextString, String:="No existe cliente",
TextOperator:=xlContains

        Selection.FormatConditions(Selection.FormatConditions.Count).SetFirstPriority

            With Selection.FormatConditions(1).Font

                .Color = -16383844

                .TintAndShade = 0

            End With

            With Selection.FormatConditions(1).Interior

                .PatternColorIndex = xlAutomatic

                .Color = 13551615

                .TintAndShade = 0

            End With

            Selection.FormatConditions(1).StopIfTrue = False

    End If

End Sub
```

Userform Used to Add Clients Manually

```vba
Private Sub Cedula_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)

'Checks if what the worker entered into the ID are numbers and returns message if they are not numbers

    If (KeyAscii > 47 And KeyAscii < 58) Then

        KeyAscii = KeyAscii

    Else

        KeyAscii = 0

        MsgBox "Solo puede insertar numeros"

    End If

End Sub
```

```vba
Private Sub Label2_Click()

End Sub

Private Sub Ok2_Click()

    Unload Me

End Sub

Private Sub Tiempo_KeyPress(ByVal KeyAscii As MSForms.ReturnInteger)

'Checks if what the worker entered into the duration of meetings entered are numbers and returns message
if they are not numbers

    If (KeyAscii > 47 And KeyAscii < 58) Then

        KeyAscii = KeyAscii

    Else

        KeyAscii = 0

        MsgBox "Solo puede insertar numeros"

    End If

End Sub
```

Appendix C: Records of Schedules Followed by Asesores

Office: Santani - Asesora: Luci Gonzalez					
Date	**Client ID**	**Full Name**	**Latitude**	**Longitude**	**Duration of Meeting (Minutes)**
01/04/16	2662300	Mariana Saldivar	-24.81347	-56.52333	100
04/04/16	3006733	Sonia Gimenez	-24.68407	-56.39026	100
05/04/16	2959833	Inocencia Insaurralde	-24.191	-56.60581	100
05/04/16	3677880	Pelagia Martinez	-24.30091	-56.42356	180
06/04/16	5237440	Liza Franco	-24.47424	-56.11873	180
06/04/16	2112120	Cresencia Esquivel	-24.68304	-56.39293	60
07/04/16	2426425	Daniela Franco	-24.97351	-56.30721	120
08/04/16	6854064	Nilsa Mancuello	-24.65923	-56.43802	120
11/04/16	5707903	Aline Duarte	-24.81529	-56.72881	100
11/04/16	1315215	Maria Estigarribia	-24.81632	-56.73366	100

Office: Ybycui - Asesora: Nancy Jimenez					
Date	**Client ID**	**Full Name**	**Latitude**	**Longitude**	**Duration of Meeting (Minutes)**
05/04/2016	4652381	Celia Gonzalez Arce	-25.933868	-57.166632	150
06/04/2016	5096363	Luisa Otazú Ranoni	-26.01547	-56.976993	240
06/04/2016	4344368	Fanny Emilse Perez Saavedra	-25.919541	-57.091409	90
06/04/2016	2314700	Georginia Torres de Cabañas	-25.878819	-57.073558	240
07/04/2016	2183648	Juana De Jesús Olazar	-26.221286	-56.756084	180

Office: Luque - Asesora: Monserrat Urbieta					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
04/04/16	1742857	Damasia Avalos	-25.306954	-57.418549	90
04/04/16	3547775	Josefina Rios	-25.268936	-57.491822	90
04/04/16	5108410	Noemi Quiñonez	-25.294604	-57.521281	90
05/04/16	820386	Jacinta Ojeda	-25.294604	-57.521281	120
05/05/16	905046	Lucia Rodriguez	-25.217808	-57.442108	90
05/05/16	3880475	Cristina Rodriguez	-25.304886	-57.43138	120
06/04/16	2008632	Graciela Torres	-25.314244	-57.389324	90
06/04/16	1478965	Patricia Palma	-25.293973	-57.417941	60
07/04/16	3956114	Julia Cabrera	-25.307456	-57.461223	30
07/04/16	889165	Teresa Martinez	-25.274551	-57.506792	90
08/04/16	1103032	Dora Rivas	-25.377237	-57.308182	90
08/04/16	1059030	Andresa Britez	-25.287521	-57.521024	150
08/04/16	1579341	Isabel Sanchez	-25.303753	-57.415289	90

Office: Ciudad del Este - Asesora: Sonia Ferreira					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
4/4/2016	3296240	Eresmilda Figueredo	-25.51279	-54.65972	60
4/7/2016	4245050	Ramona Bareiro	-25.54273	-54.61149	60
4/8/2016	819860	Sara Rosso	-25.53375	-54.6115	60
4/8/2016	2052108	Maria teresa Carbario	-25.54529	-54.60398	60

Office: Asuncion - Asesora: Andrea Gianina Burgos Pereira					
Date	**Client ID**	**Full Name**	**Latitude**	**Longitude**	**Duration of Meeting (Minutes)**
04/04/16	538863	Maria Antonia Sosa	-25.396222	-57.544898	80
04/04/16	793390	Maria Ines Bordon	-25.319238	-57.608904	80
05/05/16	4345480	Mirian Garcia	-25.400697	-57.571836	50
06/04/16	4798853	Katia Maldonado	-25.349034	-57.607852	50
06/04/16	3819235	Liz Paola Areca	-25.362467	-57.606822	40
06/04/16	1948600	Zunilda Paredes	-25.313668	-57.639803	80
07/04/16	3559225	Luz Gimenez	-25.397841	-57.564426	30
07/04/16	4345480	Mirian Garcia	-25.400697	-57.571836	30
08/04/16	4938831	Liz Castro	-25.361735	-57.606559	30
08/04/16	1347396	Nilvia Ortiz	-25.335125	-57.600347	30
08/04/16	954731	Maria Elena Vazquez	-25.360189	-57.61445	60

Office: San Lorenzo - Asesora: Lourdes Romina Molinas Ferreira					
Date	**Client ID**	**Full Name**	**Latitude**	**Longitude**	**Duration of Meeting (Minutes)**
04/04/16	1243684	Perla Garcia	-25.459906	-57.469362	80
04/04/16	873543	Sinforiana Insfran	-25.410088	-57.469768	80
05/05/16	1587277	Mirta Elena Prantte	-25.391237	-57.490136	60
05/05/16	4288147	Lucia Salinas	-25.408179	-57.483146	60
06/04/16	3893136	Antonia Alonso	-25.403293	-57.516262	20
07/04/16	1843377	Silvina Samaniego de Rodas	-25.395405	-57.519148	60
07/04/16	753197	Reinalda Isabel Aguilera	-25.305351	-57.506477	60
07/04/16	3260449	Lina Estela Ferreira Prieto	-25.288984	-57.502334	20
07/04/16	995502	Flora Aguilar de Gonzalez	-25.490212	-57.451749	20
08/04/16	3264065	Alodia Villalba Mora	-25.4962	-57.452642	60

Office: Concepcion - Asesora: Alba Ruiz					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
4/4/2016	3857622	Juliana Avalos	-23.3861	-57.437421	180
4/4/2016	4568001	Maria Magdana Sanabria	-23.3937	-57.456657	60
4/4/2016	1257125	Wilfrida Arce	-23.3907	-57.42705	60
4/8/2016	3857622	Juliana Avalos	-23.3861	-57.437421	60

Office: Coronel Oviedo - Asesora: Mirian Torres Rojas					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
4/4/2016	7,158,288	Fatima Valdez	-25.457424	-56.467	60
4/5/2016	3,734,017	Zulma Marin	-25.438693	-56.4185	30
4/5/2016	7,201,150	Liz Martinez	-25.460343	-56.445	40
4/5/2016	5,472,546	Ada Flor	-25.443569	-56.4324	40
4/5/2016	4,583,128	Juana Sosa	-25.442937	-56.4303	40

Office: Paraguari - Asesora: Maria Belen Alcaraz					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
4/5/2016	4426766	Myrian Guanes	-25.51331	-57.31226	90
4/5/2016	2106503	Germana Moreno	-25.60858	-57.26564	90
4/6/2016	5047807	Carmelina Lezcano	-25.52884	-57.26999	90
4/6/2016	2013135	Vilma Giminez	-25.55635	-57.06152	90

Office: Encarnacion - Asesora: Gladys Ojeda					
Date	Client ID	Full Name	Latitude	Longitude	Duration of Meeting (Minutes)
04/04/16	2979280	Delia Ruiz Diaz	-27.218531	-55.801485	60
06/04/16	1967206	Lidia Bravo	-27.050189	-55.559472	60
06/04/16	4112828	Soraida Duart	-27.040884	-55.575585	60
07/04/16	5922734	Maria Soledad figueredo	-27.234785	-55.810086	90
07/04/16	1,566,302	Fidelina Alcaraz	-27.360673	-55.762059	90