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A MULTI-ORGANISATIONAL APPROACH FOR DISASTER PREPAREDNESS AND RESPONSE: THE USE OF OPTIMISATION AND GIS FOR FACILITY LOCATION, STOCK PRE-POSITIONING, RESOURCE ALLOCATION AND RELIEF DISTRIBUTION

OSCAR ESTEBAN RODRIGUEZ ESPINDOLA

Doctor of Philosophy

ASTON UNIVERSITY

September 2015

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ASTON UNIVERSITY

A MULTI-ORGANISATIONAL APPROACH FOR DISASTER PREPAREDNESS AND RESPONSE

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Thesis Summary

From 1992 to 2012 4.4 billion people were affected by disasters with almost 2 trillion USD in damages and 1.3 million people killed worldwide. The increasing threat of disasters stresses the need to provide solutions for the challenges faced by disaster managers, such as the logistical deployment of resources required to provide relief to victims. The location of emergency facilities, stock prepositioning, evacuation, inventory management, resource allocation, and relief distribution have been identified to directly impact the relief provided to victims during the disaster. Managing appropriately these factors is critical to reduce suffering. Disaster management commonly attracts several organisations working alongside each other and sharing resources to cope with the emergency. Coordinating these agencies is a complex task but there is little research considering multiple organisations, and none actually optimising the number of actors required to avoid shortages and convergence.

The aim of the this research is to develop a system for disaster management based on a combination of optimisation techniques and geographical information systems (GIS) to aid multi-organisational decision-making. An integrated decision system was created comprising a cartographic model implemented in GIS to discard floodable facilities, combined with two models focused on optimising the decisions regarding location of emergency facilities, stock prepositioning, the allocation of resources and relief distribution, along with the number of actors required to perform these activities.

Three in-depth case studies in Mexico were studied gathering information from different organisations. The cartographic model proved to reduce the risk to select unsuitable facilities. The preparedness and response models showed the capacity to optimise the decisions and the number of organisations required for logistical activities, pointing towards an excess of actors involved in all cases. The system as a whole demonstrated its capacity to provide integrated support for disaster preparedness and response, along with the existence of room for improvement for Mexican organisations in flood management.

Keywords

Disaster management, multi-objective optimisation, GIS, floods, coordination and collaboration

To my parents, my brother and my wife for being my strength, motivation and inspiration every step of the way.

"Deserve your dream."
Octavio Paz

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List of Abbreviations

ACTI	Action by Churches Together International
ADH	Aktion Deutschland Hilft
ADRA	Adventist Development and Relief Agency
AGEB	Basic Geo-Statistical Area
SRAD	Search and Rescue Assistance in Disasters
CENAPRED	National Centre For Disaster Prevention
CENTRO	Municipality of Centro
DC	Distribution Centre
DEM	Digital elevation model
DIF	National System of Family Development
FONDEN	Natural Disaster Fund
GIS	Geographical information system
INEGI	National Institute of Geography and Statistics
IFRCRCS	International Federation of Red Cross and Red Crescent societies
IMSS	Social Security Mexican Institute
ISSET	Social Security Institute of the State of Tabasco
LSCP	Location set covering problem
MAEViz	Mid-America Earthquake Center Seismic Loss Assessment System
MCLP	Maximal covering location problem
MS	Management Science
MTI	Medical teams international
MXN	Mexican pesos
OCHA	Office for the Coordination of Humanitarian Affairs
OR	Operational Research
PC	Civil Protection
PMA	Presbyterian Mission Agency
REDCROSS	Mexican Red Cross
SP	Samaritan’s purse
SCT	Transport and Communications Secretariat
SEDENA	National Defence Secretariat
SEDESOL	Social Development Secretariat
SEGOB	Ministry of Interior
SEMAR	Navy
SGUERRERO	State Health Ministry of Guerrero
SMEXICO	National Health Ministry
SRE	Ministry of External Affairs

SSP	Public Security Secretariat
SSPPC	Civil Protection and Public Security Secretariat of Guerrero
STABASCO	State Health Ministry of Tabasco
SVERACRUZ	State Health Ministry of Veracruz
UNISDR	United Nations Office for Disaster Risk Reduction
USGS	United States Geological Survey
VRP	Vehicle Routing Problem
WFP	World Food program
WV	World Vision

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1. INTRODUCTION

Natural disasters are a constant threat for many countries, affecting an average of over 200 million people per year between 2000 and 2014 (CRED, 2015). It only takes one victim to begin to grasp the relevance and complexity of the activities required to provide care to and to support affected people. As a research assistant for a research project during my MSc, I had the opportunity to travel to three areas affected by floods in Mexico, talking to affected people and governmental authorities to get a better understanding of their experiences. Those conversations shed some light on the complexities related to disaster management and the relevance of informed decision-making. In this context, the focus of the activities performed is the well-being of the victims, beyond objectives used in industry. The decisions to support flood victims should contemplate fairness to avoid discrimination and political bias.

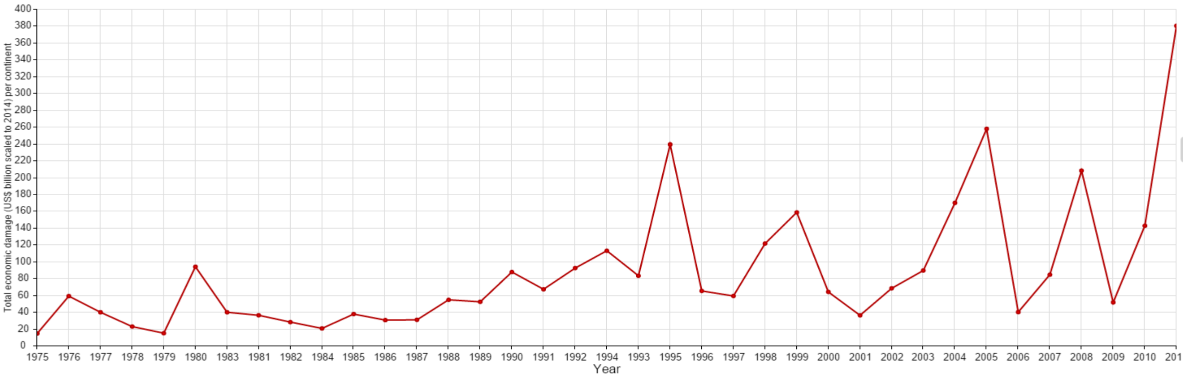
There are several activities to be undertaken to protect the people affected by disasters. Poor decision making has a large impact on disaster victims. For instance, the selection of floodable shelters, shortage of relief items, absence of human resources because of poor allocation or duplication of efforts in distribution can greatly affect the level of service provided. How to improve that decision-making is not that evident. From different discussions with authorities I realised that even though negligence plays a significant role, in several cases the problem is more related to the absence of support for guidance. Mexico is a country commonly affected by floods (Garcia, 2008), and as a result it has both a National System for Civil Protection (SEGOB, 2006a) and a dedicated budget for disaster management (Rodríguez Esteves, 2004). Despite the resources available, several issues have been identified in major disasters recently (Santos-Reyes and Beard, 2011, Santos-Reyes et al., 2010) stressing the need for the development of tools for disaster management applicable to the Mexican context. Thus, the motivation for this work is related to the tangible impact, or lack of it, of the activities performed, particularly when resources are actually available.

One technique that has been commonly used for disaster management is optimisation (Altay and Green, 2006), but the models available in the literature do not easily fit to the Mexican disaster management structure. The large number of participants, all with different resources, can create a considerable challenge to overcome if added to the complexities inherent to logistical activities such as facility location, stock pre-positioning, relief distribution and resource allocation.

The purpose of this research is to develop a tool that can be used to aid decision-making in flood situations in Mexico, so as to enable the provision of appropriate service for people at risk by incorporating multi-organisational coordination. This chapter provides an entry point for the research performed including the objectives pursued, followed by the research justification and the scope of the analysis. It concludes with the outline of the dissertation.

1.1 Current situation

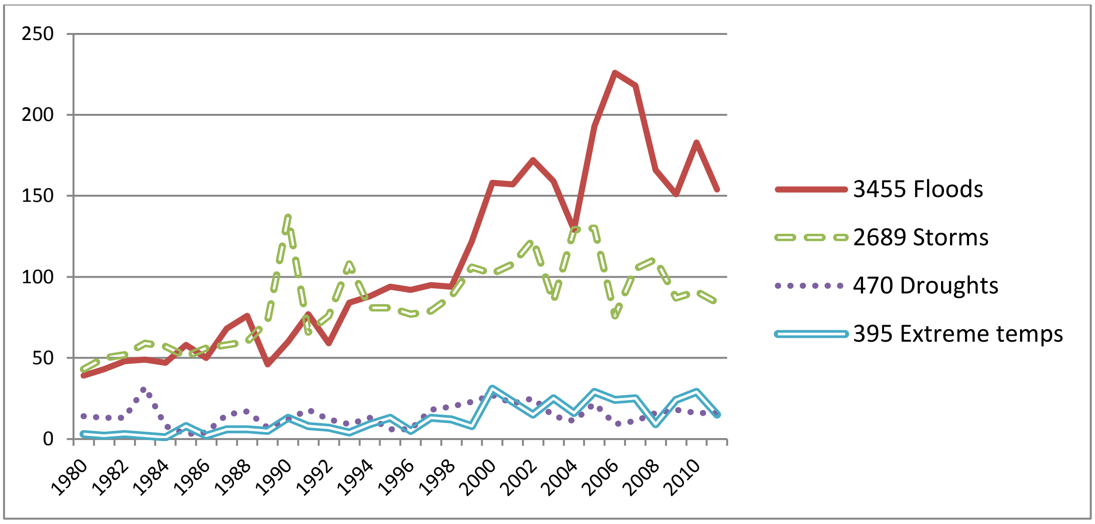
According to the United Nations Office for Disaster Risk Reduction (UNISDR), from 1992 to 2012 around 4.4 billion were affected by disasters with almost 2 trillion USD in damages and 1.3 million people killed worldwide (UNISDR, 2012). But the situations are getting worse recently. According to the World Bank, approximately 2.6 billion people were affected by natural disasters from 1994-2003, more than the 1.6 billion affected in the previous decade (IEG, 2006). Similarly, the reported economic damage caused by disasters shows an increasing trend in recent years (CRED, 2013), as it can be seen on Figure 1.1 comparing events from 1975 to 2011 scaling the damage to US dollars in 2014. Just in 2011, the total value of damage caused by disasters globally was around US$ 366.1 billion, the highest ever registered (Guha-Sapir et al., 2012).



Source: CRED (2013)

Figure 1.1. Damage caused by disasters (1975-2011)

Hydrological disasters are the most frequent and harmful (Haddow et al., 2008), as shown by Figure 1.2 by plotting the number of climate-related disasters occurred recently globally. Over 100 floods occur on average per year, and more than 150 of them occurred each year between 2007 and 2012.



Source: UNISDR (2012)

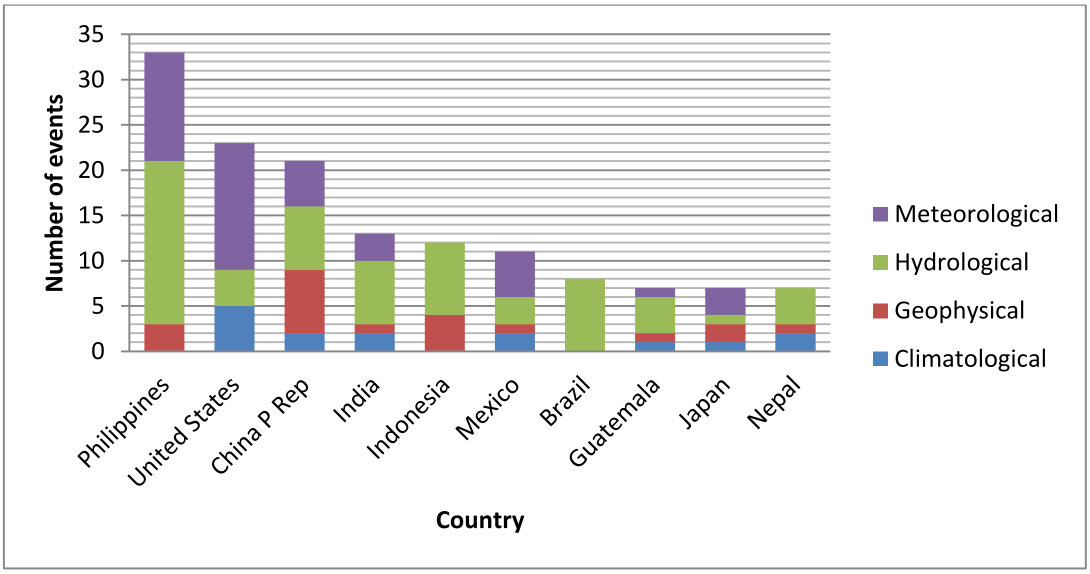
Figure 1.2. Number of climate-related disasters around the world (1980-2011)

These changes have been reflected to some extent in the academic literature, attracting the attention of researchers (Kunz and Reiner, 2012), leading to many journal publications (Caunhye et al., 2012) and even the creation of journals focused on the topic (Kovács and Spens, 2011). However, research in this area for developing countries is only now beginning to be undertaken, while over 70% of disasters between 1970 and 2009 have occurred in such countries (Julca, 2012).

The impact of disaster events can vary widely between developed and developing countries (Julca, 2012). The lack of resources, poor urban planning, and high vulnerability are reasons behind the steep impact of disasters on these countries. For that reason, more research regarding the challenges faced by developing countries is required (Kovács and Spens, 2011). For instance, in 2011 over 57% of the reported damage by disasters was due to the earthquake and Tsunami in Japan. That represented a financial impact of 3.9% of the country's GDP, whereas disasters in the same year in El Salvador and Cambodia had an impact corresponding to 4.7% and 4.6% of the countries' GDPs respectively (Guha-Sapir et al., 2012).

1.2 Disasters in Mexico

Figure 1.3 shows the ten countries with the greatest number of disaster events reported in 2011, with Mexico in sixth place with eleven events. The majority of disasters in that country were caused by meteorological and hydrological phenomena. The future holds something similar. According to estimations, between 20 and 50 years from now one of the most flood-affected states of Mexico, Tabasco state, could be covered by water (Hernández, 2013, Pérez, 2009).



Source: Guha-Sapir et al. (2012)

Figure 1.3. Top 10 countries by number of reported events in 2011

The number of people affected by disasters is an even greater concern. In 2011, Mexico had the tenth highest number of victims caused by disasters worldwide with 3.7 million (Guha-Sapir et al., 2012). From 1950 to 2015 the country has suffered 241 reported large-scale disasters representing more than 7.5 percent of the total number of disasters in 47 countries analysed in the Americas (CRED, 2016a). That number makes Mexico the most affected country by disasters in the Americas after the United States (CRED, 2016a), with an average occurrence of nearly 4 large-scale disasters per year in the last 65 years.

The country has also been deeply affected financially by disasters. For instance, the State of Tabasco has experienced estimated economic damage equivalent to 192 million US dollars, $2.4 billion US dollars and $405.5 million US dollars in 1999, 2007 and 2008 respectively (Zapata et al., 2011). Just the ten top disasters in Mexico have caused an estimated damage of US $26,024,000,000 (CRED, 2016b) from a total reported damage of US $43,629,210,000 from 1950 to 2015 in the country (CRED, 2016a). That means that Mexico has suffered nearly 4.4% of total damage caused by disasters in the Americas in 65 years, the second highest value just surpassed by the United States (CRED, 2016a). That is evidence that Mexico is a country that has been deeply affected by disasters.

The case of Mexico is also interesting because it has the second largest economy in Latin America but nearly 50% of the population lives in poverty (World_Bank, 2013). It is an economically stable country but with high levels of marginalization and vulnerability. Despite the severe damage caused by disasters in Mexico, the country is not as dependent on international aid as other developing countries, as shown by the limited number of times the country has requested international aid in recent disasters situations (SRE, 2014). The country counts with the resources to actually prepare and react to floods (Rodríguez Esteves, 2004).

Experience in previous disasters has demonstrated the poor performance of current procedures used by authorities, in spite of incurring considerable costs. For instance, sheltering was a significant issue in the flood of Villahermosa in 2007, due to a lack of prepared shelters (Barbozay and Morales, 2007, Notimex, 2007, Urrutia and López, 2007), facilities flooded (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011), and the demand exceeding the capacity provided by the authorities (OCHA, 2007b, Santos-Reyes et al., 2010, Uribe and Enriquez, 2007). This obliged the government to open government buildings to shelter some people in need (El_Universal, 2007). It is believed, however, than more than one million people affected by the disaster could not find shelters (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011).

Relief distribution became a significant issue as well because of shortages of food (Dudley, 2007, OCHA, 2007b, Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011), medicines (Notimex, 2007) and supplementary items (Notimex, 2007). This created a fear of social instability (Jiménez, 2007) and provoked episodes of looting (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011). There was a lack of personnel to distribute relief (Barbozay and Morales, 2007) and there was evidence of uneven coverage partially due to political interference (Dudley, 2007, Hernández, 2009), impeding the provision of relief to high priority communities.

There are two main issues in current Mexican flood preparation and planning: 1) resources are not being used efficiently among different agencies, and 2) the protection provided for the affected people is poor, at best. Unsafe and unprepared facilities used to shelter people, delays in deliveries, shortages on stock, and inefficient allocation of human resources and goods are results of the absence of proper mechanisms for disaster preparedness and response.

A major goal of this research is to provide evidence than tools suited for floods in Mexico can be developed to provide better support in terms of location, allocation and distribution decisions, with the aim of providing the necessary care and protection for affected populations and ensuring the efficient use of resources by considering multiple organisations and avoiding duplication of efforts.

1.3 Flood preparedness and response

So far, we have shown that a lot of disasters occur around the world, from which floods and other hydrological disasters form a large proportion of these. Different types of disaster require different types of response (Cozzolino, 2012, De Leeuw et al., 2012) given the varying features of each type of hazard. Among all disasters, floods are one of the most common (Tehrany et al., 2013, Ajin et al., 2013) and destructive phenomenon world-wide (Patel and Srivastava, 2013, Sarhadi et al., 2012).

Unlike other sudden disasters such as earthquakes, floods can provide more time to react (Kunz and Reiner, 2012) because these are more easily predicted and prevented compared to other disasters (Chang et al., 2007).

Considering physical aspects such as geography and topography are relevant for floods. For example, hydrological analysis of regions and basins (Diaz and Isuhuaylas, 2001) makes it possible to predict floods using return periods (Ward et al., 2011), obtain probability distributions to forecast floods based on rainfall situations (Esteves, 2013) and generate mapping tools to estimate water heights and damaged zones (Liebscher et al., 2012).

Flood prevention is usually related to mitigation including the development of tools to reduce risk (Haddow et al., 2011). There are situations that cannot be prevented, calling for preparedness and response measures to reduce the damage caused by disasters (El-Sergany and Alam, 2012). Flood preparedness encompasses the readiness of a region to cope with a disaster based on the decisions and activities performed before the disaster occurs (Crowther, 2010), whereas disaster response involves activities during disaster to mitigate damage (Altay and Green, 2006). Adequate planning and preparedness can significantly improve disaster response activities. For example, on the east coast of India, after a major cyclone in 1977 with a death toll around 20,000 people, an early warning system, meteorological radars and emergency plans were established. These systems proved their worth in 1996 and 2005 where the death tolls were 100 and 27 respectively (UNISDR, 2009) for similar cyclones to de one in 1977.

The relationship between preparedness and response is apparent in the close interaction between the activities undertaken on both phases. For instance, prompt relief distribution in the response stage is subject to the availability of relief supplies and the location of emergency facilities.

Research in the area is pointing towards the development of models providing efficiency and effectiveness of emergency operations in the field. Efficiency is associated to resource performance metrics aiming to seeking to cover as much as possible of system's objectives with minimum resources, whereas effectiveness is related to output performance metrics seeking to maximise the amount of requirements satisified (Beamon and Balcik, 2008). For example, in the field of humanitarian logistics several articles are aiming to minimise the use of resources under certain requirements (e.g. Ozbay and Ozguven, 2007, Sheu, 2007b, Noyan, 2012) as a measure of efficiency, or maximising the number of people serviced with certain resources (e.g. Mete and Zabinsky, 2010, Salmeron and Apte, 2010, Altay, 2013, Najafi et al., 2013, Chang et al., 2014) as a measure of effectiveness.

Despite of the advances on the field, some of the most common challenges still encountered are related to avoid the need for re-evacuations because of the closure of damaged facilities (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011), delays in distribution (See PAHO, 2010), relief shortages and the absence of prepared personnel to undertake distribution (OXFAM, 2012, IFRCRCS, 2012). These decisions rely on having the resources to perform them efficiently. Research in the area needs to focus on the joint participation of different organizations.

Government agencies play a major role in aiding vulnerable population. But in reality, governmental agencies are just one of the actors, as illustrated by Figure 1.4.

Source: Nolte et al. (2012)

Figure 1.4. Organisations involved in large-scale disasters

Considering the large number of organisations involved, Perry (2006) identified elements such as coordination, culturally sensitive assessment, information sharing, local leadership, and lack of knowledge that affect the emergency logistics planning as relevant drivers for successful operations. Focusing on the use of human and material resources, coordination and collaboration are crucial for the efficient management of the actors involved for disaster preparedness and response. Even just among governmental organizations, the autonomy of many of them results in a need for coordination and cooperation to try to cope with the emergency. This is particularly important for developing countries, where resources are even scarcer (Nolte et al., 2012, Quero, 2012).

Disaster situations are so complex that the natural reaction is to send every resource available to provide support. However, having more actors involved is not bounded to get better operations. Increased complications in coordination along with underused capacity can result from that situation. Part of the challenge associated with the deployment of resources is to determine how many organisations to involve, and perhaps more importantly, which ones are needed.

1.4 Aim and objectives

The aim of the proposed research is to develop a system for disaster management based on a combination of optimisation techniques and geographical information systems (GIS) to aid multi-organisational decision-making regarding the location of shelters and distribution centres, the amount of prepositioned stock of relief items, the allocation of material and human resources, and relief distribution for floods in Mexico.

To accomplish the aim, the research has undertaken the following:

- An analysis of current research focused on facility location, stock pre-positioning, resource allocation and distribution, both independently and combined, so as to understand in greater depth the context of the problem, and to place the proposed research in the context of existing academic literature.
- Evaluate the capabilities of the combination of raster and vector GIS to understand the impact of floods on a particular geographical location.
- The development of a methodology integrating geographical analysis with optimisation for the location of emergency facilities, the amount of prepositioned stock of relief items, relief distribution and the allocation of resources.
- The design of two optimisation models to integrate preparedness and response in a consistent decision-making process.
- The application of the methodology to three study cases in Mexico to evaluate the results obtained from it and its performance across cases.

In order to reach the objectives, the following questions are addressed in this research:

- RQ1: Is the system proposed adequate to aid decision-making on floods in different regions in Mexico?
- RQ2: How does the use of geographical analysis affect the policy applied for disaster management?
- RQ3: Is there a difference for disaster preparedness and response between having coordinated agencies and independent agencies?
- RQ4: Can a methodology based on GIS and optimisation be built to determine the location of emergency facilities, stock prepositioning, relief distribution and allocation of resources, and improve the activities currently performed by Mexican authorities?

1.5 Scope of the thesis

The scope of this research is restricted to the location of facilities, stock pre-positioning, relief distribution and allocation of resources for cases of flood. The system developed will focus only on preparedness and response, right before the process of bringing activities back to normality.

The literature review includes only studies focused on humanitarian logistics related to the topics addressed, incorporating papers addressing natural disasters or without disaster specification. Humanitarian logistics share many similarities with commercial logistics, particularly with transient supply chains (Day et al., 2012), but there are unique features of emergency situations that differ from classic logistics (See Van Wassenhove, 2006). This research is portrayed within the framework of humanitarian logistics.

Evaluation of the system developed will be undertaken using past data from real floods in Mexico. Given the chaotic nature of disaster management, some information was not recorded by the authorities, and here optimised results have been used in order to provide the *best* possible combination of real activities for comparison.

The development of the system has been based on the multi-agency disaster response structure used by Mexican authorities. The system is intended to be used in that country and any adaptations to other geographical areas should be address carefully.

1.6 Contribution

The expected outputs of the system would be: the location of emergency facilities, the allocation of people to shelters, the allocation of pre-positioned inventory, the amount of relief items to ship, the transportation mode, the allocation of shipments between emergency facilities, the number of resources required per agency, the activation of agencies required to face the situation, and the allocation of human and material resources per organisation.

As noted previously, it is important to design such a methodology because currently Latin American authorities do not have an optimised mechanism for decision-making in flood episodes (Rodríguez-Espíndola and Gaytán, 2015).

The contributions of the proposed research can be summarised as follows:

- The development and analysis of a system for flood management, addressing facility location, stock pre-positioning, resource allocation and relief distribution using a multi-organisational perspective; an approach never undertaken before.
- Design of a system for flood preparedness and response based on the Mexican context.
- Analysis of coordination and interoperability as crucial elements for disaster management.
- Analysis of the value of the use of GIS for disaster preparedness.

The contributions of the system are:

- The integration of vector and raster GIS capabilities as input into a system for disaster preparedness and response.
- The novel multi-organisation bi-objective multi-commodity multi-modal preparedness model incorporating equity for planning before the disaster happens.

- The novel multi-organisation bi-objective multi-commodity multi-modal response model considering equity to develop a reactive plan after the disaster occurs.
- The inclusion of material and human resources as constraints for flood management.
- Balance between efficiency and effectiveness in both models.
- The inclusion of a performance measure for each model considering items and services provided on shelters.

The contributions to theory can be summarized as the demonstration of the advantages of a system for disaster management encompassing activities of preparedness and response, the value of the use of raster and vector GIS for flood management, and the analysis of a multi-organisational approach for disaster preparedness and response. The contributions to the practitioners are the system itself and the proof that the inclusion of this tool for decision-making holds the potential to improve current solutions.

1.7 Thesis structure

This section introduces the main content of each chapter to provide an outline of the overall dissertation. The thesis encompasses eight chapters, described as follows.

Chapter 1, Introduction, is focused on the motivation for the problems addressed, the nature of the problem and the importance of research in this area. Also the aims, objectives, scope and contribution of this research are presented.

Chapter 2, Theoretical Framework, introduces several relevant concepts for the research at hand including the clarification of basic definitions, the framework under which this research operates and the description of the main aspects of the techniques included.

Chapter 3, Literature Review, includes the analysis of the literature in humanitarian logistics. It introduces an in-depth analysis of literature focused on facility location, stock pre-positioning, resource allocation, and relief distribution within the context of humanitarian logistics. The gap existent in the literature and the opportunity areas filled by this work are identified. Finally, the Mexican disaster management framework is reviewed to use as base for the design of the models.

Chapter 4, Research Methodology, details the methodology used for the development of this work. It includes the research paradigm in which the research is positioned, the research design and the methodological choices used including the assessment methods applied to evaluate the results of this work.

Chapter 5, System Design, explains each one of the structural parts of the system developed, detailing the rationale, design and steps towards application. It also elaborates on the solution methods for the models and the verification performed to ensure the appropriate functioning of each one of them.

Chapter 6, Case Studies, deals with the application of the system proposed to three case studies in Mexico. Each one of the cases is explained including details of the area and the conditions of the disaster faced, data sources and data collection, the application procedure, the results obtained and the discussion of results.

Chapter 7, Evaluation and Discussion, presents the analysis of results obtained from each one of the cases and the assessment of them, including the evaluation of the models under different instances.

Chapter 8, Conclusions and Future Work, undertakes the summary of the research developed to assess the research questions, identify the contributions provided and mention niches for future research.

1.8 Chapter Summary

This chapter has introduced the research undertaken for disaster preparedness and response. Initially the problem posed by disasters and especially floods has been described, elaborating on the value of the study for disasters in a developing country such as Mexico. Next, the aim and objectives pursued by this work are presented along with the reach of the study and contributions. Finally the content of each chapter is described.

The next chapter elaborates on the main concepts required to appreciate the content of this research; including the main features of humanitarian logistics, the classification of GIS and the characteristics of multiobjective optimisation.

2 THEORETICAL FRAMEWORK

The purpose of this section is to introduce and clarify the main concepts and techniques used for the development of this research. Firstly, the concept of disaster, its typology and the context associated with disaster management are introduced. Then, of the concept of humanitarian logistics is defined and the framework of logistical operations is presented. Finally, the definition and classification of the tools used in this research are explained.

2.1 Disaster concept and definitions

Drabek (2007) identified the definition of disaster as a key issue faced by many researchers at the time of providing advances on the field. The first formal definition was provided by Fritz (Perry et al., 2006, Quarantelli and Dynes, 1977), who stated a disaster occurs when "*the social structure is disrupted and the fulfillment of all or some of the essential functions of the society, or its subdivision, is prevented*" (Fritz, 1961). There are several studies looking into the definition of disaster and its evolution in social sciences (Fischer, 2003, Perry et al., 2006, Drabek, 2007, Quarantelli, 2005), however there seems to be little consensus about the matter. Quarantelli (2005) concluded that the definition of disaster often relies on the purpose and audience of the study (Perry et al., 2006).

Departing from the purpose of the present study, the definition considered comes from the literature on humanitarian logistics. On the Second Session held by UNISDR at Geneva in June 2009, a disaster was defined as a "*serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope using only its own resources*" (UNISDR, 2009). Based on that concept, for the purposes of this research a disaster is understood as *an extreme situation that requires the deployment of resources to mitigate the effect on society*.

Considering the common association of disasters with emergencies, it is important to define the latter as well. According to Oxford (2015), an emergency can be defined as "*a serious, unexpected, and often dangerous situation requiring immediate action*". Commonly in the Sociology literature, authors consider two types of emergencies: everyday emergencies and severe emergencies; none of them reaching the level of disaster (Altay and Green, 2006, Fischer, 2003).

It has been be argued that emergencies and disasters vary mostly on scale, scope and time (Fischer, 2003). To bridge that gap, the concept of large-scale emergencies has been introduced as an extension of severe emergencies. Large-scale emergencies are "*rare events that overwhelm local emergency responders and require regional and/or national assistance, such as natural disasters and terrorist attacks*" (Jia et al., 2007a). As a result, disaster management has been considered as a subset of emergency operations (See Haddow et al., 2008, Davis and Lambert, 2002, Schneider, 2013), with the acceptance of catastrophes as extreme disasters (Fischer, 2003). This dissertation supports that view, understanding that not every emergency is a disaster, but considering every disaster as a situation that qualifies as an emergency on large scale bases

Fischer (2003) proposed the scale showed on Table 2.1 to classify events in terms of degree of disruption, scope of the area covered and duration of the disruption. This work is relevant to the third category (DC-3) and above.

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The nature of the phenomenon is also relevant, because different hazards require different planning and preparedness (Cozzolino, 2012). Disasters are commonly classified depending on its origin and its speed of development. According to their origin disasters can be natural or man-made, whereas in terms of speed of development these can be classified as sudden-onset and slow-onset. Table 2.2 exhibits some examples of disasters according to the classification introduced by Van Wassenhove (2006). The research presented here is focused on floods under the umbrella of natural sudden-onset disasters, because floods usually develop in a matter of hours or days (Haddow et al., 2008).

Table 2.2. Types of disaster

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Figure 2.1 shows a taxonomy of natural disasters, from which this research will put special attention on floods. According to UNESCO (2012), floods can be defined as a "*rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate*". Although that definition is highly accepted and accurate, it is not clearly considering urban floods caused by raining. For the terms of this research, a flood is understood as the *overflow of natural water bodies and/or the accumulation of water affecting areas commonly dry*.

Floods are usually caused by prolonged rainfall, onshore winds, intense thunderstorms, snowmelt, ice jams, and dam failures (Haddow et al., 2008). These features show the inherent geographical nature of floods (Armenakis and Nirupama, 2013).

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Source: Guha-Sapir et al. (2012)

Figure 2.1. Natural disasters classification

2.2 Emergency management

Natural phenomenon originates emergency situations which societies have to address through 'emergency management'. Emergency management is a very broad discipline focused on the *analysis of risks in order to prevent them or deal with them, encompassing natural, man-made, sudden-onset and slow-onset disasters* (Haddow et al., 2008).

Similar to the case of disasters and emergencies, disaster management is understood as a subset of emergency management. Disaster management represents "*the range of activities, prior to, during and after the disasters, designed to maintain control over disasters and to provide a framework for helping at-risk persons and/or communities to avoid, minimise or recover from the impact of the disasters*" (Singh, 2008). The difference between both concepts is related to scale, scope and time, but emergency management is a broader concept and this research will focus only on disaster management working within the umbrella of emergency management.

The study of emergency management is commonly accepted to have started with the dissertation developed by Prince (1920). Most of the research comes from the time after World War II (FEMA, 2015, Quarantelli and Dynes, 1977), further fuelled by the Cold War during the 1950s (Haddow et al., 2008). Mitigation, preparedness, response and recovery have been identified in emergency management as relevant phases, from which Drabek and Hoetmer (1991) defined the 'Comprehensive Emergency Management Framework'. The framework has been adopted in disaster management and it is used in this research to classify the stages before and after the disaster based on the four phases. The phases are sometimes overlapping, and they are a continuous cycle, as shown in Figure 2.2.

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Source: Drabek and Hoetmer (1991)

Figure 2.2. Phases of the comprehensive disaster management

Mitigation is the stage focused on *identifying and performing activities avoiding or reducing the risk that the disaster occurs*. Hazard identification and mapping, land use planning, financial incentives, insurance and structural controls are some of the tools for risk mitigation (Haddow et al., 2008). It is the most studied of the four phases (Altay and Green, 2006).

Preparedness involves *activities intended to help communities respond to any possible disaster* (Caunhye et al., 2012). Quite a lot of research on this phase is related to facility location (e.g. Balcik and Beamon, 2008, Chanta and Sangsawang, 2012, Zhao et al., 2012) and stock pre-positioning (e.g. Campbell and Jones, 2011, Rawls and Turnquist, 2010).

Response takes place i*n the moments before, during and after the disaster strikes and is related to the use of resources to protect life, property, the environment and the social structure* (Altay and Green, 2006). The research on this phase has been focused on activities such as evacuation (e.g. Bretschneider and Kimms, 2011, Kimms and Maassen, 2012, Scheer et al., 2012), search and rescue (e.g. Chen and Miller-Hooks, 2012, Lakshmi Narayanan and Ibe, 2012, Wang and Wang, 2008), inventory management (e.g. Jaller et al., 2008, Yung-Lung et al., 2008), and relief distribution (e.g. Banomyong and Sopadang, 2010, Nolz et al., 2011).

Recovery is the phase focused on *stabilizing the community and bringing the situation back to normal circumstances after a disaster* (Altay and Green, 2006). There are some papers related to life sciences and economics looking at the spread of diseases (e.g. Jordan et al., 2011, Santos et al., 2009, Westhoff et al., 2008), the allocation of displaced people (e.g. Nikolopoulos and Tzanetis, 2003), infrastructure assessment (e.g. Chang and Nojima, 2001, Cret et al., 1993, Song et al., 1996), and reconstruction (e.g. Kim and Dshalalow, 2002).

In disaster situations there are activities carried on previous to the occurrence of the disaster and after the disaster strikes. Previous to the disaster the mitigation and preparedness phases are relevant. Mitigation is understood as the activities when the occurrence of a disaster is unknown and structural measures are used to avoid such situations, whereas preparedness is a stage where the disaster can or cannot be known but activities are related to plan activities and resources necessary to protect the population.

At the stage after the disaster happens, response and recovery are the phases that occur. Response includes the point from which the disaster starts until it the threat is considered finished. This phase incorporates the activities to aid victims when danger is very high. Afterwards, recovery is the stage where society is brought back to normal conditions.

Based on the objectives of the proposed research, this research is focusing on disaster preparedness and response because of their direct relationship to the protection provided to disaster victims during the disaster event.

2.3 Logistics for emergency management

Within the framework of emergency management, logistics is a sector responsible for as much as 80% of the expenditure of aid agencies (Christopher and Tatham, 2011, Trunick, 2005). Moreover, logistics is crucial to organizational success during crises (VanVactor, 2012), serving to bridge the gap between preparedness and response (Thomas and Mizushima, 2005).

2.3.1 Definitions

The definitions of emergency logistics and humanitarian logistics contain many elements in common. Humanitarian logistics is defined as "*the process of planning, implementing, and controlling the efficient, cost-effective, flow and storage of goods and materials, as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary's requirements*" (Thomas and Mizushima, 2005). The above is widely accepted because it is based on the classic definition of logistics (http://cscmp.org/about-us/supply-chain-management-definitions) with the subtle switch from customers to beneficiaries.

Under the umbrella of humanitarian logistics there are two main areas of study: continuous aid work and disaster relief, as seen in Figure 2.3. Continuous aid work is focused on slow-onset situations such a drought or famine, whereas disaster relief is targeting situations caused by disasters mostly in sudden-onset instances (Kovács and Spens, 2007).

Source: Compiled by author with information from Kovács and Spens (2007)

Figure 2.3. Components of Humanitarian Logistics

The term emergency logistics arises as a "*a process of planning, managing and controlling the efficient flows of relief, information, and services from the points of origin to the points of destination to meet the urgent needs of the affected people under emergency conditions*" (Sheu, 2007a).

Because of the commonalities between both concepts, these have been used interchangeably in the literature. As this research is focused on floods, the overlap between natural disasters and emergency events causes this topic to be covered by both concepts. However, it is important to highlight that none of the concepts is a subset of the other. Emergency logistics includes every type of emergency, from which only large-scale emergencies are covered by humanitarian logistics. On the other hand, Humanitarian logistics includes continuous aid work, which in turn is not covered by emergency logistics. For the purposes of this research the concepts of humanitarian logistics and emergency logistics are used interchangeably, both focused on natural disasters only.

Until recently, humanitarian logistics have been a much neglected field by research, and in need of efficient tools for effective management (Ortuño et al., 2011, Van Wassenhove, 2006, Kovács and Spens, 2007). From the 1970s (Caunhye et al., 2012) it has been growing rapidly because of the impact of recent disasters as well as examples of inappropriate aid and poor relief operations (See Bogard, 1988).

Even though humanitarian logistics share many similarities with commercial logistics, there are key differences such as unpredictability of the demand (Balcik and Beamon, 2008, Whybark et al., 2010), command and control issues (Whybark et al., 2010), shortage of resources (Balcik and Beamon, 2008), death and suffering at play (Balcik and Beamon, 2008, Whybark et al., 2010), donor independence and individually driven interests (Kovács and Spens, 2009, Tatham and Spens, 2011, Whybark et al., 2010), shifting priorities over time (Apte, 2009, Van Wassenhove, 2006, Whybark et al., 2010), changing operational needs (Whybark et al., 2010), self-initiated participants (Drabek and McEntire, 2003, Nilsson et al., 2010, Wachtendorf and Kendra, 2004) and the large number of players (Whybark et al., 2010). In that sense, it is the view of this research than humanitarian logistics requires research tailored to the characteristic features of catastrophic situations, and any models or concepts drawn from commercial logistics ought to be adapted to these characteristics.

2.3.2 Framework for disaster operations

After a literature review, Caunhye et al. (2012) identified a framework in emergency logistics comprising some of the most relevant activities involved in preparedness and response, displayed in Figure 2.4. According to the literature review presented on the next chapter, this framework is missing inventory management and resource allocation. Inventory management was proposed as one of the future research directions by the authors, whereas resource allocation was only studied in terms of relief as part of other activities. For the purposes of this research, the framework presented is supplemented with resource allocation and inventory management to classify and analyse logistical activities. This section introduces the definition for each one of them.

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Figure 2.4 Framework for disaster operations

2.3.2.1 Facility location

The purpose of these papers is *to determine the number and location of facilities to provide support for disaster victims* (Jia et al., 2007a). Facility location models can be used to determine the location of supply facilities (Falasca and Zobel, 2011), shelters (Sherali et al., 1991) or emergency services (Indriasari et al., 2010). This activity affects the protection and provision for affected people, and also in the relationship of these decisions to other activities such as evacuation (Li et al., 2011) and relief distribution (Horner and Downs, 2010).

2.3.2.2 Stock prepositioning

Stock prepositioning is a useful method to expedite availability of resources for immediate response (Rawls and Turnquist, 2010). Pre-positioning is *the storage of relief goods for post-disaster distribution on locations close to the potential disaster* (Ukkusuri and Yushimito, 2008). This strategy improves disaster response by totally or partially disposing of procurement delays (Bozkurt and Duran, 2012), reducing the distribution lead-time (Ukkusuri and Yushimito, 2008). Nonetheless, the uncertainty of the occurrence and magnitude of the event can complicate the adequate allocation of resources (Oloruntoba and Gray, 2006), yielding very high costs.

2.3.2.3 Evacuation

This widely studied stream of research (Horner and Downs, 2007, Mas et al., 2013) is defined as "*the mass physical movement of people, of a temporary nature, that collectively emerges in coping with community threats, damages or disruptions" (Quarantelli, 1980)*. As seen in Figure 2.4, evacuation can be performed in the preparedness phase or at the response stage. Evacuation models can refer to large-scale situations such as disasters or small-scale situations such as building evacuations (Mas et al., 2013).

2.3.2.4 Relief distribution

Relief distribution is the "*delivery from local distribution centres or from central warehouses to a population in need*''(Balcik et al., 2008). The main challenge is to provide sufficient essential supplies as quickly as possible to disaster victims (Sheu, 2007b), directly affecting suffering and survival rates (Yi and Kumar, 2007). This is a highly complex activity due to limited resources, damaged transportation infrastructure, limited communication and multiple actors (Inampudi and Ganz, 2009, de la Torre et al., 2012).

2.3.2.5 Casualty transportation

The *transportation of wounded patients after disaster from the affected area to centres to receive medical treatment* (Jin et al., 2014) is denominated casualty transportation, and it makes a significant difference in terms of the death toll (Najafi et al., 2013).

2.3.2.6 Inventory management

According to Whybark et al. (2010), there is very limited research available concerning the problem of disaster inventories, which focus on *the determination of size and frequency of orders, and safety stock levels* (Falasca and Zobel, 2011). The main difference with commercial inventory management is that having relief items available is far more important than transportation and storage costs; diminishing the relevance of keeping low levels of inventory (Long and Wood, 1995).

2.3.2.7 Resource allocation

The activities above have a common assumption of resource sharing among them. For instance, people can be used for warehouse management and also for shelter operation; similarly vehicles can be used for casualty transportation and relief distribution. The concept of resource allocation arises as the *deployment of available resources taking into account the needs of the affected people they will be serving* (Anaya-Arenas et al., 2014). It involves the allocation of available resources to a set of activities for the system to operate (White, 1993).

As the flow of relief items and people affected is portrayed in the framework, there is also the need to integrate the allocation and deployment of resources as a relevant logistical activity (Anaya-Arenas et al., 2014). In developing countries, constraints in resource allocation are very common because of scarce resources (Sanyal and Lu, 2009).

A main feature of resource allocation is balance; often the problem is not only to have enough resources (Quarantelli, 1983), but also to avoid convergence (i.e. excess) of items, people and information (Wenger et al., 1986, Fritz and Mathewson, 1957). To achieve appropriate balance, effective communication and coordination between the actors involved is needed, and thus the allocation of resources is intrinsically related to these factors.

2.3.3 Coordination in humanitarian logistics

A disaster is a situation needing the involvement of institutions from different functional disciplines and jurisdictions (Chen et al., 2007). In fact, commonly governmental agencies, public international organisations, international non-profit organisations and civil groups along with local non-profit organisations are all involved in disaster management (Nolte et al., 2012). Bearing in mind most of these organisations vary considerably in terms of culture, purpose, priorities, standards, capacity and expertise (Balcik et al., 2010), with the potential to cause bottlenecks in aid flows (Oloruntoba, 2005); de la Torre et al. (2012) identified coordination of multiple agents as one of the unique challenges of disaster management.

Drabek (2006) discussed how several of the concepts of coordination existent in the Sociology literature are not suitable from the humanitarian perspective. For the purposes of this research, coordination is understood as "*the cooperation of independent units for the purpose of eliminating fragmentation, gaps in service delivery, and unnecessary (as opposed to strategic) duplication of services*" (Gillespie, 1991). Therefore, the multi-organisational perspective used here is looking to achieve *the alignment, organization and allocation of resources from different actors to deliver products and services among different beneficiaries and different areas*, as defined by Nolte et al. (2012). Balcik et al. (2010) divided coordination into horizontal and vertical to clarify the relationships between different actors. Horizontal coordination relates to the liaisons of one actor with agents on the same level of the supply chain, whereas vertical coordination is conceptualized as the relationship of one organisation with other agents involved in upstream or downstream activities. This research is focused on horizontal coordination between different agencies.

The absence of adequate coordination can prevent successful emergency response (Chen et al., 2007), because it is key to maintain the balance between shortages and oversupply. Without coordination, the different actors might compete for the same scarce resources (Balcik et al., 2010), as exemplified by the "truck crisis" that took place on Haiti in 2010 (Holguín-Veras et al., 2012). The problem was not the lack of relief aid but transportation means for delivery. On the other hand, oversupply can also represent a relevant issue because of convergence (Balcik et al., 2010), given the extra resources needed to sort unnecessary items and the complications created by having too many people. For instance, more employees require more resources such as equipment, increases safety issues (Abounacer et al., 2014) and there is the potential of congestion (Wenger et al., 1986).

Coordination has been clearly identified before as a significant challenge for relief distribution (Balcik et al., 2008, Chen et al., 2011), but it also affects other logistical activities. Disorganised opening of sheltering facilities, duplication of efforts for search and rescue, excess of unnecessary items in warehouses, among others are only some examples of the challenges created by the absence of coordination between actors.

However, to improve coordination when faced with mass casualty incidents is very complicated (Wilson et al., 2013). Handling combined resources to attain the best possible care for disaster victims represents a very complex task, even for governmental agencies alone. Nonetheless, the nature of the challenges mentioned above creates an opportunity for analytical techniques from Operational Research (OR) and Management Science (MS) to try to find a suitable solution (Altay and Green, 2006). For instance, finding the right balance of resources to use can be characterised as 'optimising' the use of such resources, which is the approach undertaken in this research.

2.4 Operational Research in disaster management

2.4.1 Definition

Operations Research is "*a scientific approach to decision making, which seeks to determine how best to design and operate a system, usually under conditions requiring the allocation of scarce resources*" (Winston, 2004). OR has its origins in the Second World War to allocate resources efficiently for military strategic campaigns (Dym, 2004, Ramos et al., 2010). Nowadays the attractiveness of OR for disaster management is the potential to minimise loss of lives and money through efficient use of resources. It also allows the inclusion of fairness and standards of humanitarianism through the use of mathematical expressions (de la Torre et al., 2012). Techniques portrayed in the OR spectrum have the potential to handle multiple objectives, resource constraints and uncertainty, making these techniques an appropriate approach for disaster management (Bozkurt and Duran, 2012).

Among the broad set of techniques available in OR, Altay and Green (2006) and Galindo and Batta (2013) identified mathematical modelling as the most common of these used in disaster management. The next section elaborates on the value of optimisation in the context of disaster management and also introduces relevant concepts used in this dissertation.

2.4.2 Optimisation

2.4.2.1 Definition

Optimisation models are defined as the *representation of a system used to determine the maximum/minimum of a mathematical function* (Verma and Boyer, 2010, Mital, 2007). Optimisation models are prescriptive models (Askin, 1993) characterized for their ability to evaluate several options seeking to find the optimal combination to obtain the best value (maximum or minimum) of one (or more) objective(s) (Mingers, 2003). The main components of these models are controllable parameters used to alter the objective function referred as decision variables; one or more criterion to be optimised called objective functions, and a set of conditions that define the feasible region (Verma and Boyer, 2010).

The purpose of this approach is to obtain an abstraction from reality (Skyttner, 2005) in the form of a system of mathematical expressions that encompass the essence of the problem (Simonović, 2009). In disaster management, the challenge is to create a model as close as possible to reality (Simonović, 2010), but avoiding excessive complexity. That system should encompass the interaction between actors inside the society, and between the society and the disaster.

Amongst optimisation models several classifications can be identified. For instance, models can be static or dynamic, linear or nonlinear, deterministic or stochastic, among others. The following sections present classifications based on linearity and number of objectives, which are relevant for this research and affect the solution method mechanisms.

2.4.2.2 Classification based on linearity

Depending on the variables included on the model two broad classes can be defined: linear models and nonlinear models. Linear programming deals with optimisation models in which all equations and inequalities are linear (Verma and Boyer, 2010). Albright and Winston (2009) mentioned three important properties possessed by linear models:

- Proportionality. Affecting a variable times a factor results in a change of the same magnitude of the factor in the contribution to objective functions/variables in which the variable is involved.
- Additivity. The sum of the contributions from all the activities to a specific constraint equals the total contribution of the constraint.
- Divisibility. Both integer and continuous values are allowed for the variables.

However, some real-world problems are more complex and cannot hold the properties above. Nonlinear models are formulations in which the objective(s) and/or the constraints are not linear (Albright and Winston, 2009). These models can provide more accurate representations of reality, but with increased difficulty to solve (Albright and Winston, 2009).

There is a class of models that contain linear equations but in which the variables do not comply with the divisibility property of linearity (Winston, 2004). Trucks, people or buildings cannot be used in decimal terms. For situations in which some or all of the variables ought to take integer values (Askin, 1993), mixed-integer programming and integer programming are used (Winston, 2004). Moreover, this class of models can deal with 0-1 variables called binary variables (Albright and Winston, 2009).

Integer models are more difficult to solve than linear problems (Albright and Winston, 2009, Verma and Boyer, 2010), but less complex than nonlinear models. The research presented in this thesis lies within this category.

2.4.2.3 Classification based on the number of objectives

One of the main components of the model is the expression to be optimised. Although several models are focused on optimising a single objective function, there are situations where more than one objective are relevant (Albright and Winston, 2009), as exemplified by the complexity of disaster situations (Beamon and Balcik, 2008).

Single objective models contain only one objective function to optimise whereas multiobjective optimisation models contain two or more criteria, usually in conflict with each other (Fernández and Huelin, 2007). The former can find an unique optimal solution, whereas the latter is characterized by a p-dimensional vector of solutions (Simonović, 2009).

That set of efficient solutions is also known as Pareto Optimal (See Pareto, 1896) or noninferior solution (Ehrgott, 2000), presenting a set of *trade-offs.* A *trade-off* is a compromise of improving one objective at the cost of worsening the other.

A nondominated point is a feasible solution that is not improved in all the performance measures by any other feasible solution (Sawaragi et al., 1985). The graph of the objective functions in which their nondominated vectors are part of the Pareto optimal set is known as Pareto frontier (Coello, 2005). Figure 2.5 shows an example of the Pareto frontier for a problem with two objective functions, exhibiting the trade-off between both performance measures. The reader is referred to Ehrgott (2000) and Sawaragi et al. (1985) to read more about dominance, definitions and properties of solutions.

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Source: Coello (2005)

Figure 2.5. Pareto frontier

2.4.2.4 Solution methods for integer optimisation models

Solution methods for these problems can be broadly divided in two: exact and heuristics. An exact algorithm can guarantee the convergence to the optimal solution (Beasley, 2013), whereas a heuristic algorithm uses a logical method to obtain an acceptable solution in a reasonable amount of time (Askin, 1993). The latter are used commonly to avoid an otherwise monumental amount of resources or because the parameters of the problem are beyond the reach of known exact procedures (Beasley, 2013).

Among exact algorithms, branch and bound (See Land and Doig, 1960), complete enumeration (See Winston, 2004) and cutting planes (See Taha, 2008) are the most relevant ones. On the other hand, some of the best known types of heuristic algorithms are evolutionary algorithms (See Simon, 2013) and local search algorithms (See Doerr and Auger, 2011).

The methods mentioned above have to be integrated with larger solution techniques in order to get the set of efficient points for multiobjective models. For this purpose, Baños (2006) provided a review of the main categories of Multi Objective Evolutionary Algorithms

(MOEAs), whereas Ehrgott (2005) introduced scalarization techniques and nonscalarizing methods.

This work will focus on two scalarization methods; the weighted-sum method and the ε-constraint method.

Weighted-sum method

This is a very traditional method to obtain the Pareto set by weighting the objective functions of the problem and changing those weights systematically (Kim and de Weck, 2005). This method takes *n* number of objective functions and provides a unique equation through the sum of the functions weighting every term. The function to optimise can be expressed as follows:

$$g_0(x) = \sum_{i=1}^{k} p_i f_i(x)$$

Where p_i is the weighting factor and $f_i(x)$ the objective functions. There is a possibility of the sum of the weights equalling one. However, the problem identified with this method is related to convexity, as it is not able to obtain the efficient set when the boundary is nonconvex (MATLAB, 2003).

ε-constraint method

Another common solution technique is the ε-constraint method. Instead of weighting objectives, one of the objective functions is optimised while the other(s) are used as constraint(s), changing the constraint value systematically to obtain the efficient set (Ehrgott, 2005). The advantage of this method is that all the efficient solutions can be found (Ehrgott, 2005). The general formulation for *n* objective functions can be seen below:

$min/\,max\, f_i(x)$ $\qquad\qquad$ $\forall x \in X$

Subject to $f_j(x) \leq \varepsilon_j$ $\qquad$ $\forall j = 1,2,\ldots,n; i \neq j$

The reader is referred to Ehrgott (2005) for more information about these solution methods and the theoretical analysis of theorems.

2.5 Geographical Information Systems

2.5.1 Definition

Geographical information systems have been developed since the 1960s (Delaney, 1999, Chang, 2002) and are defined as a "*computer system for capturing, storing, querying,* *analysing, and displaying geographic data*” (Chang, 2002, p.2). This kind of systems allows the user to perform an analysis based on the spatial world, using geographical variables.

It is important to look at these systems as an aid for decision making and not misunderstand them as isolated solutions for spatial problems (Delaney, 1999). Because of that reason, GIS have developed successfully in areas such as civil engineering, mathematical studies, soil science, urban planning, resource management and transportation (Burrough, 1986, Thévenin and Banos, 2011, Chang, 2002).

Moreover, GIS is very suitable to combine with logistic models (Jian-Kun et al., 2010) because of its capability to perform network analysis using layers of roads.

2.5.2 Data structures

The main components of GIS are software, hardware, liveware and data as shown on Figure 2.6. There are two types of widely recognized data: spatial data and attribute data. The former focuses on locating the elements studied in space (e.g. coordinates of the region), whereas the latter contains features at a spatial location (e.g. population in the city) (Delaney, 1999). Spatial data is represented in two possible ways: vector data or raster data (Chang, 2002). These data structures affect the manipulations the user can perform, and there is software capable of handling only one of them or sometimes both (Delaney, 1999).

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Source: Delaney (1999)

Figure 2.6. Components of GIS

The difference between these data structures can be seen on Figure 2.7, with raster data represented on the left hand side and vector data on the right hand side. Vector data is represented using *x,y* coordinates to build points, lines and polygons (Chang, 2002), i.e. the features resemble items on a map (Delaney, 1999). A vector GIS represents more accurately spatial location at the cost of higher data storage and computing power (Delaney, 1999).

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Source: Delaney (1999)

Figure 2.7. GIS Data structures

Among a broad range of applications, vector data is widely used for purposes of design and transportation. In terms of design it is highly used to create blueprints, whereas for transportation applications a road network can be created using lines, whereas polygons can be used to represent demographic areas.

Raster data is a "*gridded array of cells, or pixels, that are assigned a numeric value*" (Frels et al., 2011). Raster data is based on square cells referenced by a row, a column and a key code used to identify the attribute being mapped (Burrough, 1986). Even though raster data has lower spatial accuracy than vector data (Delaney, 1999), it is easier to handle and it is compatible with remotely sensed imagery. These features make raster data ideal for the analysis of continuous phenomena (Reibel, 2007), as it can deal with aerial photography and satellite imagery (Frels et al., 2011).

For this research, the capabilities of vector and raster data are included. Vector data is used for network analysis and physical representation of the urban design of the areas; whereas raster data is used to deal with digital elevation models (DEMs). DEMs are "*representations of the continuous variation of relief over space*" (Burrough, 1986), i.e. are maps in which each cell contains elevation data of the region. These layers are used as input for the cartographic model in order to analyse the impact of the flood.

2.5.3 GIS for disaster management

GIS represent helpful tools for emergency management (Chang, 2002, Cova, 1999, Feng and Wang, 2011, Radke et al., 2000, van Westen, 2002) because disasters are located in the intersection between physical and social (Crooks and Wise, 2013). It allows the user to analyse geographical conditions of the event and it can display results graphically to understand the emergency situation easily (Jian-Kun et al., 2010, Lee et al., 2011). That is why many organisations including the United Nations have GIS units (Kaiser et al., 2003). There has been an argument about the cost limitations to generate GIS data for developing countries (Kaiser et al., 2003), however some publicly available data had begun to bridge that gap (See Chang, 2002).

There are several potential contributions of GIS to different disaster management phases (Cova, 1999). For instance, Feng and Wang (2011) elaborated on projects involving GIScience such as the use of satellite images and microwave measures for flood forecasting and flood control planning, modelling tsunami propagation and inundation, coordinating rescue teams, managing real time data, among others. Moreover, GIS have proven very effective for hazard identification, risk assessment, early warning, evacuation, facility location, search and rescue, demographic analysis, disease distribution and land use analysis (Armenakis and Nirupama, 2013, Cova, 1999, Kaiser et al., 2003, van Westen, 2002).

Raster GIS has been successfully used for flood modelling before (Zerger and Wealands, 2004). Satellite data has been used to identify potentially dangerous areas, detect early stages of anomalies for forecast, plan evacuation routes, design centres for emergency operations, damage assessment, coordination of search and rescue operations, among others (van Westen, 2002). Furthermore, GIS has been integrated with mathematical programming for flood management (e.g. Chang et al., 2007, Chanta and Sangsawang, 2012), but it can be integrated with other techniques and methods as well (Hui et al., 2011).

2.6 Chapter Summary

This chapter introduced on some of the main definitions to establish the context of the research at hand. It started from the concept of disaster and elaborated on the phases and activities of emergency management. Also some of the technical aspects of this work were introduced to provide the basis about the tools and techniques used, including a brief explanation about optimisation and GIS.

The next chapter presents an extensive literature review of humanitarian logistics for natural disasters to introduce the works existent in the area, identify the gap currently present in the current literature and place this research as a contribution to tackle that gap.

3 LITERATURE REVIEW

3.1 Introduction

Meaningful contributions and valuable insights usually are based on deep understanding of the field of study and thorough analysis of the work previously done in the area. This chapter includes a survey of previous studies with the intention to understand further the area of emergency logistics, and to place this research in the literature. This dissertation will elaborate on literature focused on humanitarian logistics for preparedness and response, particularly looking at the location of emergency facilities, stock-prepositioning, resource allocation, and relief distribution; incorporating also a brief mention of other activities related to them.

A narrative literature review presented here was performed to analyse deeply the contributions from articles in the literature. The narrative review is introduced in this chapter to understand common approaches undertaken previously and to identify the gap tackled by this research. Finally, the Mexican disaster management framework is briefly introduced to understand the general structure and rationale for the development of the models.

3.2 Previous reviews

The literature on disaster management has been scrutinized under different perspectives in the past, collecting the main contributions, and analysing the trends and gaps in the literature. The main features of each one of the reviews identified can be seen on Table 3.1, including the period comprised in the analysis, the focus area and the techniques included.

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Using a traditional approach, Wright et al. (2006) focused on the use of OR for events related to homeland security. The authors included the analysis of different contributions to each area according to the content of the article and the functional stage. Drawing attention to humanitarian logistics, Kovács and Spens (2007) provided a classification of the literature based on three operational stages (viz. preparation, response and reconstruction) to give an overview of their findings. From the results and analysis of the differences between humanitarian logistics and commercial logistics, the authors developed a framework for disaster relief logistics.

Undertaking content analysis, Caunhye et al. (2012) focused on optimisation models for emergency logistics to create a taxonomy of articles by objective, constraints and type of model. More recently, Kunz and Reiner (2012) performed a meta-analysis of situational factors, context of operation, speed of start, cause of disaster, phase and research methodology.

Regarding systematic reviews, Simpson and Hancock (2009) focused on the use of OR for emergency response including both common emergencies and large-scale emergencies. The aim was to identify trends in volume, focus or outlet. A very comprehensive study of the use of OR and MS in disaster management was developed by Altay and Green (2006), undertaking a review to provide information about the affiliation of the authors, OR methodologies used, disaster type addressed, operational stage and research contribution. Following that review, Galindo and Batta (2013b) provided an updated version adding an analysis of the assumptions on the papers and changes in the trends in recent years.

The literature reviews aforementioned are not including papers developed until 2015 nor incorporating all the activities studied here. Even though Caunhye et al. (2012) considered optimisation as the focus of their review, the authors did not elaborate on the type of objectives used, solution methods or the time dimension of the models (i.e. static or dynamic). Furthermore, the role of GIS in emergency logistics in combination with optimisation has not been studied thoroughly. Finally, the value of coordination in activities related to humanitarian logistics along with resource allocation has been understudied; aspect analysed further in this thesis.

3.3 Narrative literature review

This section reviews some of the main contributions provided in the literature in detail. Each one of the logistical activities identified on Section 2.3.2 was examined independently and in combination with other activities, placing particular attention on articles using optimisation models and GIS. For the models, the solution method is only mentioned when it is different than commercial software.

3.3.1 Facility location

The purpose of facility location is to determine the number and location of facilities to provide support for disaster victims (Jia et al., 2007a). These decisions have steep impact on cost and responsiveness (Haghani and Oh, 1996), but in emergency logistics factors such as safety and accessibility play an important role as well (Alçada-Almeida et al., 2009). Facility location greatly affects other decisions within emergency logistics (Caunhye et al., 2012), as evidenced by the number of integrated approaches found in the literature.

The focus of this area can be towards the location of supply facilities, shelters or emergency services, portraying a very strong link to other main activities.

3.3.1.1 Shelter location

Shelter location refers to the selection of shelters among different facilities to protect affected people. This decision can drastically affect the impact of a disaster on the victims (Chou et al., 2013). Shelter location has been studied independently, combined with evacuation and also associated with stock prepositioning.

<u>Location of shelters</u>

The increasing awareness of the importance of shelter location is encouraging researchers to look at the location of these facilities independently. There is research on tents and transportable facilities (Becker, 2009, Fadhil et al., 2009, Gupta, 2015), and site selection for shelter construction (Dalal et al., 2007, Wei et al., 2012, Mirzapour et al., 2013, Liu et al., 2011, El-Anwar et al., 2009). However, in many countries shelters are located on established public facilities such as schools (Liu et al., 2011, Kar and Hodgson, 2008). For instance, in Mexico transportable tents are mostly used for operations abroad, and commonly the selection of shelters is performed from a list of public buildings (SEDENA, 2010).

This section is not looking on shelters only as destination of the evacuation, but as facilities that should comply with a set of attributes to improve logistical operations. Focusing on the selection of buildings, two main streams were identified in the literature. The first one is related to the assessment of shelters, where each facility is analysed according a set of criteria to create a ranking of buildings. These include the use of multi-attribute models to obtain the weight of each factor for assessment of facilities (Xu et al., 2008, García et al., 2010), the analysis of shelters of shelter attributes using GIS (Alam, 2000, Sanyal and Lu, 2009, Gall, 2004, Kar and Hodgson, 2008, Cheng-An et al., 2010b, Yung-Lung et al., 2008), the combination of GIS with multi-attribute decision models (Wen-bin et al., 2011, Dou et al., 2012) and the combination of GIS with fuzzy models (Tsai et al., 2008). These articles are looking at creating a hierarchical list of shelters, but they are not really deciding which shelters should be opened. More importantly, several desirable shelters could be very close by in one region, whereas in another area only undesirable shelters could be available. Thus, this research is focused on prescriptive models seeking to provide the optimal location of shelters.

Considering the service nature of the facilities, covering problems are common. Pan (2010) focused on the maximisation of coverage based on the maximal covering location problem (MCLP) using capacity constraints, whereas Wei et al. (2012) integrated a location set covering problem (LSCP) and a MCLP, solving the former initially to determine the minimum number of facilities required to satisfy all demand, including then the solutions in the latter to ensure complete coverage.

Using the idea of clustering villages, Dalal et al. (2007) applied the Elzinga-Hearn algorithm to calculate the minimum maximum distance travelled by affected people from their households to the facilities. Similarly, Mirzapour et al. (2013) used clusters for demand and provided a model to minimise the maximum expected weighted distance from facilities to demand regions.

Approaching the problem based on the p-center problem, Huang et al. (2010) used dynamic programming with the assumption of facility failure and transference of aid. The model is looking to minimise the maximum weighted distance between a node and its nearest facility. It is solved performing a binary search over the coverage distance.

Focusing more on the solution method than the problem, Hu et al. (2012) developed a discrete particle swarm algorithm seeking to minimise the number of shelters to open.

Incorporating more than one performance measure, El-Anwar et al. (2008) designed a location-allocation model aiming to minimise negative socioeconomic impacts on displaced families, maximise their safety, minimise adverse environmental impacts, and minimise total public expenditures. The weighted-sum method is employed to generate optimal trade-off solutions. More recently, Zhao et al. (2012) developed a model to determine the location of shelters looking to minimise shelter points, minimise investment, maximise number of escape refugees and maximise the escape rate.

In cases of disaster the physical dimension is very important. Liu et al. (2011) stressed this by using a qualitative approach to determine guidelines for shelter selection based on remote sensing images. The purpose was to find sites away from risk taking into account the accessibility of mountainous areas. Prathumchai and Samarakoon (2005) used vector GIS to include flood depth, road surface density, road accessibility, slope and capacity in the location decision.

Using GIS for data pre-processing and network analysis along with multi-objective optimisation, El-Anwar et al. (2009) merged the model developed by El-Anwar et al. (2008)

with GIS. The result was an automated system integrated into the Mid-America Earthquake Center Seismic Loss Assessment System (MAEViz) software encompassing three main models: data collection, automated optimisation and output analysis and visualization. Later on, El-Anwar et al. (2010) extended that work by developing a three-part methodology: a safety model to measure and quantify temporary housing safety, a cost model to minimise total public expenditures on temporary housing and a multi-objective model to maximise the former and minimise the latter solved through an automated weighted-sum method. More recently, Chanta and Sangsawang (2012) used the capabilities of GIS to find potential shelters in the region to introduce into the bi-objective model solved using the epsilon-constrained method. The model is aiming to maximise coverage and minimise the total weighted distance.

But GIS is not the only way to consider the physical effect of the disaster, as shown by Chowdhury et al. (1998). The authors combined hydrologic simulation and optimisation. The former establishes the spatial distribution of flood depth, whereas the nonlinear model determines how to allocate shelters to zones by using three objective functions: minimise total risk, maximise the range of protection, and minimise the total risk measure for each zone. The solution method chosen was a greedy heuristic.

The papers above are creating the demand for relief distribution; however there is no apparent consideration about those activities. Tackling that, Sharawi (2007) developed a deterministic, a stochastic and a robust approach for the allocation of people and stock prepositioning to shelters. The model seeks to minimise cost on the first two models and the maximum deviation of unmet demand over all scenarios for the third one. But only Li et al. (2011) linked shelter location- allocation, stock prepositioning and post-disaster supply, proposing a two-stage stochastic model. The first stage decides locations, capacities, and held resources of new shelters whereas the second stage allocates evacuees and resources to shelters. The goal of the first stage is to minimise overall cost for both stages, whilst the second stage aims to minimise transportation costs, surplus and shortage costs. The authors proposed the L-shaped method to decompose the problem.

From the articles presented it is noticeable that deterministic approaches are the most common, only accounting for the damage of disaster base on the geographical analysis or considering backup facilities.

Only Li et al. (2012) considered human resources in the formulation even though this resources can constraint the availability to open facilities. Looking at the objectives presented, none of them is related to the service provided in the shelters, which can be logical due to the absence of consideration of human resources.

Shelter location and evacuation

Shelter location is considered a critical activity for evacuation (Sherali et al., 1991), and it has been studied either considering fixed facilities for trip destination, or selecting facilities. In the former, authorities have a set of pre-determined shelters, focusing on developing models for trip destination as reported by Southworth (1991). The purpose of these articles is to determine the probability of evacuees selecting one shelter (Charnkol et al., 2007, Mesa-Arango et al., 2013, Cheng-An et al., 2010a), allocate residents to facilities (XU et al., 2007), assess the willingness to pay for shelter construction (Ono and Schmidlin, 2011) and/or to evaluate shelters as possible destinations (Chou et al., 2013, Cheng-An et al., 2010a, XU et al., 2007, Hadiguna et al., 2014). However, the research presented here is focused on the decision about where to open shelters.

Using optimisation, Sherali et al. (1991) proposed a nonlinear location-allocation model aiming to minimise the total time spent by all the traffic on the network, and it is solved through a heuristic procedure and an exact implicit enumeration algorithm.

Bi-level models have been used to introduce different stakeholders, considering authority decisions on the upper level and choices of the evacuees on the lower level. Kongsomsaksakul et al. (2005), Ng et al. (2010), Shen et al. (2008), Kulshrestha et al. (2011) and Li et al. (2012) used that approach and incorporated user equilibrium for the formulation. Kongsomsaksakul et al. (2005) and Ng et al. (2010) focused primarily on travel time of the evacuees to decide shelter allocation and let the victims decide their own route, whereas Li et al. (2012) minimised the weighted sum of unmet shelter demand on the upper level and travel time on the lower one. The models were solved using a genetic algorithm, simulated annealing, and Lagrangian relaxation with scenario decomposition for the cases of Kongsomsaksakul et al. (2005), Ng et al. (2010) and Li et al. (2012) respectively.

Incorporating uncertainty into bi-level approaches, Shen et al. (2008) and Kulshrestha et al. (2011) considered stochastic demands focusing on minimising evacuation time and total cost respectively. Shen et al. (2008) considered stochastic distances and used a α-reliable mean-excess regret model (See Chen et al., 2006) solved using a genetic-based algorithm and a simulation algorithm for the routing strategy, whereas Kulshrestha et al. (2011) based on a logit model and proposed a cutting plane algorithm to solve the problem.

Uncertainties related to road damage (Yazici and Ozbay, 2007), facility damage (An et al., 2013) and demand (Song et al., 2009) have been addressed. Yazici and Ozbay (2007) explored the inclusion of probability constraints for damaged roads into a Cell Transmission based system optimal dynamic traffic assignment formulation. The objective was to minimise system-wide travel time and the model is solved by using the P-Level efficient points method (Prékopa, 1990). The results show that accounting for flood probabilities, even for links not used by all evacuees, can change the system-optimal flows and performance measures, impacting shelter locations and capacity requirements. An et al. (2013), considered risk of disruptions in a model looking to minimise the total expected system cost from facility set-up and evacuation operations across scenarios. Their study concluded that the higher the probability of disruption, the larger the number of facilities required. Song et al. (2009) proposed a location-routing problem to optimise bus routing and passenger pick-up points. The aim of the model is to minimise the total evacuation time incorporating demand uncertainty and it is solved using a hybrid genetic algorithm merged with hill climbing.

The uncertainties aforementioned are based on the physical damage caused by the disaster. As a result, the inclusion of tools to provide an assessment of the situation appears to be a necessity. Sallee (2011) elaborated on the importance of GIS for emergency management and exemplified it on a project locating public storm shelters by using watersheds to analyse a flood control dam. The 'what if' scenario for dam failure showed the value of the inclusion of GIS. The combination of optimisation and GIS was explored by Ye et al. (2012), who applied ArcGIS for the spatial analysis, whilst Dijkstra's algorithm was used to minimise evacuation distance, and afterwards an algorithm was used to maximise the covering population. Chen et al. (2013) used GIS to consider the spatial distribution of shelters and nearby facilities, and to determine distances. They designed an optimisation model that minimised the weighted total distance from the demand points to the immediate shelters and the relocation distance.

A paramount challenge for all of the models presented above is the fact that disaster relief operations are multi-objective by nature (Haghani and Oh, 1996). In facility location there are multiple of factors affecting the decision (Yu et al., 2009). Even though several authors are reluctant to apply this type of modelling given the difficulty of the solution (Caunhye et al., 2012), there is an increasing number of researchers proposing multi-objective models recently.

Among papers using multi-objective optimisation and GIS, Saadatseresht et al. (2009) proposed a three-step procedure: the identification of safe places for evacuation using aerial/satellite image processing, the allocation of facilities to each demand area, and the determination of optimum routes through a model aiming to minimise total distance travelled by the population and maximise the capacity use of shelters, solved using NSGA-II. Alçada-Almeida et al. (2009) designed a p-median model seeking to minimise total travel distance, total risk in the primary path, fire risk at shelters, and total time required to transfer people from shelter to hospital. The model is solved through a combination of the weighted-sum method and goal programming, using SIGUrb to calculate the distance of each solution from its ideal solution. Coutinho-Rodrigues et al. (2012) extended that paper considering backup evacuation paths and adding two objectives: minimisation of total risk of the evacuation paths and minimisation of the total number of shelters.

Looking back at the articles described on this section, there are different approaches to address possible damage caused by disaster. There are stochastic approaches including the probability of failure of some element, and also papers incorporating GIS to evaluate the situation. Most of the single objective models are focusing on minimising travel time, only with a couple of contributions minimising cost (i.e. An et al., 2013, Kulshrestha et al., 2011) and distance (i.e. Chen et al., 2013, Ye et al., 2012), which is putting a larger weight on evacuation. Multi-objective models are including time but also performance measures focused on the facilities such as number of shelters, risk or use of capacity. Still, the approaches presented are considerably more focused on evacuation, and none of them are considering the need of human resources to manage the facilities.

3.3.1.2 Emergency facility location

Emergency facilities in a regular context are related to medical facilities (Berman et al., 2005, ReVelle et al., 1977, Basar et al., 2011), fire stations (Toregas et al., 1971, Toregas et al., 1974) or simply generic facilities to provide a service (Neebe, 1988, Uno et al., 2007, Liu and Huo, 2011, Indriasari et al., 2010, Canbolat and von Massow, 2011). Nonetheless, the literature has extended to the location of emergency facilities for disaster situations.

Aiding the location of medical facilities for disaster situations, Han and Zhang (2009) used a genetic algorithm (GA) to solve a location model to minimise cost and an allocation model aiming to maximise the help effect produced by the emergency units. Including stochastic demand and road damage, Abdollahi Demneh et al. (2011) designed a p-median problem to determine the number and location of facilities seeking to minimise the damage due to delays and total cost in a combined objective function.

Looking at generic emergency service facilities, Li et al. (2009) introduced a deterministic model aiming to maximise time satisfaction considering an acceptable travel time. The model was solved using a Particle Swarm Optimisation (PSO) algorithm. Including risk factors for accidents, Wang and Zhang (2011) presented a model using a similar approach to Wei et al. (2012) encompassing two steps: on the first one a location covering model is to determine the number of facilities needed to satisfy the demand while reducing cost, whereas on the second stage a MCLP is undertaken looking to maximise the value of the coverage based on the priorities of different areas. Accounting for uncertainty, Ma and Zheng (2011) provided an algorithm incorporating uncertainty in demand aiming to minimise the weighted distance to the facility, whereas Mitsakis et al. (2014) included the probability of a wildfire to develop a simulated annealing algorithm in MATLAB used to minimise the weighted sum of the maximum and average response time to an emergency.

Regarding rescue facilities some deterministic approaches have been developed. Chai et al. (2011) proposed a model aiming to cover all the demand whilst considering economic factors in the decision. The model aims to minimise cost and is solved by a heuristic embedded into a genetic algorithm. Wenfeng and Zhenping (2013) included the impact of disaster losses in a model minimising the combination of expected property losses at all demand points, the rescue costs for all the facilities and the operation cost also of every facility. Xi et al. (2013) provided a modified p-median model aiming to minimise total distance and set-up cost in the same function, introducing a neighbourhood search-based algorithm for the solution.

Concentrating on the location of disaster recovery centres for FEMA in Florida, Dekle et al. (2005) proposed the use of vector GIS software to perform spatial analysis to determine potential locations for facilities. Each facility is weighted according to security, safety, accessibility, site requirements and equipment. Finally, an uncapacitated LSCP seeks to minimise the total number of centres needed.

Standing between the applications for disaster and common emergencies, Doerner et al. (2009) developed a three-objective optimisation model for the construction of public facilities as schools in areas near coast, taking risks of inundation by tsunamis into account. The objectives incorporate a weighted average of the minisum criterion and the maximal coverage criterion, the minimisation of tsunami risk obtained and the minimisation of cost. Finally, the authors proposed a solution based on a variant of NSGA-II.

The articles sampled in this section are displaying different applications to facility location within the disaster management context, evidencing a dominance of the traditional performance measures such as cost, time and distance. Also, this area involves mostly articles considering only one performance measure, except for Doerner et al. (2009), who shows the potential improvements attainable by the use of multiple objectives. As seen on independent shelter location, there are articles tackling the impact of the event by either using stochastic components or the aid of GIS. Finally, none of the articles is involving human resources or multiple actors.

3.3.1.3 Location of supply facilities

The location of facilities used to storage and distribute relief items can enhance response capabilities, shorten lead times and decrease operational costs (Jinhui et al., 2009).

Similar to shelter location, the location of supply and storage facilities independently has been studied from the perspective of assessing facilities to choose the most desirable ones and using prescriptive models to determine the optimal facilities to include. Among the ranking methods, there are approaches based on the use of standalone AHP (Roh et al., 2013), AHP and fuzzy theory (Turgut et al., 2011), AHP and Shannon entropy (Jinhui et al., 2009, Huang and Xie, 2009), AHP and Fuzzy-TOPSIS (Roh et al., 2015), AHP and DEA (Deqiang and Xiaoming, 2011), and agent-based simulation (Turner et al., 2011).

Considering the purpose of this research, the literature review is focused on the use of decision models aiming to provide the optimal combination of facilities to operate. Tackling the problem with a deterministic approach, Hale and Moberg (2005) developed a method based on a LSCP aiming to minimise the number of facilities, whereas Zhang and Yang (2007) and Tzong-Heng et al. (2011) focused on minimising cost by applying genetic algorithms for the solution. The former proposed a p-median formulation with service radius constraint, whilst the latter addressed the decision of warehouse location along with hub location on two different hierarchical levels, and the allocation of distribution channels between them.

Moving away from the traditional metrics and trying to encompass the requirements of disaster management in only one expression, the new “social cost” functions appear. Yushimito et al. (2012) analysed the problem using Voronoi diagrams and optimisation to maximise coverage of affected regions while minimising human suffering through the use of a social cost function. The function is based on a distant-dependent function of urgency, and the uncapacited non-linear model is solved by a heuristic based on Voronoi diagrams.

Incorporating uncertainty, Jia et al. (2007a) presented a model for facility location adaptable to cast as a covering model, a p-median model or a p-center model seeking to maximise coverage, minimise the total service distance or minimise the maximum service distance for all demand points, respectively. The models include the possibility of road disruption and multiple coverage through different distances to tackle demand uncertainty. Jia et al. (2007b) used the same strategy with an uncapacitated model aiming to maximise covered facilities at different quality levels. The authors developed three heuristics to solve the location problem: a genetic algorithm heuristic, a locate–allocate heuristic, and a Lagrangean relaxation heuristic. Later on, Lu and Hou (2009a) developed a variation of Jia et al. (2007a) considering different likelihoods of impact of the emergency per area. They proposed a model based on the MCLP to maximise demand covered by multiple facilities solved by an Ant Colony Optimisation (ACO) algorithm. Building upon that, Lu and Hou (2009b) introduced a grey degree version of Lu and Hou (2009a).

Using chance-constraints to deal with demand uncertainty, Murali et al. (2009) introduced a MCLP with a loss function to account for the distance-sensitive demand. The paper introduced a deterministic and a chance-constrained model, both aiming to maximise coverage. More recently, Xiang-lin et al. (2010) used fuzzy theory considering the likelihood of occurrence of a disaster and its impact to propose a queuing MCLP aiming to maximise satisfied demand solved through an ACO algorithm.

Accounting for the risk of the studied areas, Akgün et al. (2015) used a fault tree analysis approach calculated as the multiplication of the probability of the threat, the vulnerability of the demand point, and possible loss at the demand point due to the threat. The paper introduced a vertex p-center model to determine the distance to consider in the analysis and a 'p-Center Risk Model' to provide facilities to cover the whole demand. The former aims to minimise the maximum distance between demand nodes and the nearest facility, whereas the latter minimises the maximum risk that demand points are exposed to.

Focusing on the damage to the road network after disaster, Lu and Sheu (2013) provided a robust vertex p-center model accounting for uncertain travel times. The aim of the model is to minimise worst-case deviation in maximum travel time between distribution centres (DCs) and affected areas from the optimal solution. The solution methods proposed included a local search-based algorithmic and a specific implementation based on simulated annealing. Based upon that, Lu (2013) provided a robust vertex p-center model seeking to minimise worst-case deviation in maximum weighted distance from the optimal solution.

Incorporating facility disruption, Li and Ouyang (2010) designed a continuum approximation model for different scenarios, considering the failure of some facilities and the resilience of the system to still satisfy relief requirements aiming to minimise total cost. Later on, Hong et al. (2012) based on Horner and Downs (2007) to develop two robust facility location models considering backup facilities and the use of capacity constraints to include possible damage. The models look to minimise a combination of set-up cost and weighted distance. Afterwards, Jeong et al. (2014) provided a procedure encompassing an efficiency-oriented model seeking to minimise transportation cost, a risk-oriented model to minimise the expected risk cost for shut-down of facilities, and a trade-off model that takes upper and lower boundaries from the other models to determine the trade-offs using a weighted-sum.

Relying on the use of multi-objective models and the weighted-sum method for solution, Zhang et al. (2011) combined a set-covering and a p-median approaches to design a model aiming to minimise the total cost of location opening whilst minimising travel time between depots and emergency points. Maliszewski et al. (2012) focused on the location of critical infrastructure aiming to improve the protection of assets. The p-dispersion model seeks to maximise the minimum distance between two facilities, and it is used to show the suitability of multi-objective approaches by evaluating the performance of such objective along with the p-median and p-centre. Later on, Zhang et al. (2013) explored disaster location from a Steiner tree perspective. They model minimises the total length of the system and the maximal distance between facilities and demand points. It is solved using a population-based pattern-matching algorithm called stochastic diffusion search.

Undertaking a multi-objective approach and a stochastic perspective, Snyder and Daskin (2005) incorporated the use of backup facilities in two bi-criteria models: a reliability p-median problem and a Reliability Fixed-Charge Location Problem, the latter allowing the construction of additional facilities. Both models aim to minimise a weighted sum of the operating cost and the expected failure cost using the weighted-sum method, having in mind that each facility fails with a given probability, and multiple facilities may fail simultaneously.

There is a set of contributions combining optimisation with GIS for data analysis. Widener and Horner (2011) based on Teixeira and Antunes (2008) to explore the use of the hierarchical capacitated-median model with maximal travel distance constraints. GIS is used to identify accessible relief facilities and the model is aiming to minimise travel cost. Considering random failures on the distribution roads, Salman and Yücel (2015) designed a model aiming to maximise expected demand coverage using a scenario-based approach and prioritising areas expected to be more damaged. The authors proposed a tabu search heuristic to solve the problem.

Exploiting GIS, multi-objective optimisation and applying the weighted-sum method for solution, Horner and Downs (2007) proposed a general network flow modelling approach to identify accessible locations. The model minimises the assignment costs of servicing break of bulk points from warehouse locations and minimises assignment costs between facilities. TransCAD®, vector GIS, was used to manage the spatial data input and to visualize relief planning scenarios. Later on, Maliszewski and Horner (2010) developed a model for facility construction through a combination of the p-median and p-maxian problem. The model aims to maximise the total weighted distance from all potential targets to each facility and to minimise the total weighted distance of populations assigned to their closest facility. Providing a risk-based methodology, Zhao and Chen (2015) used GIS to identify severity and vulnerability, mapping risk, and using the results as input in a three-objective optimisation model. The model aims to maximise coverage, minimise total weighted distance and minimise the maximum distance between a demand unit and the supply facility. The latter was included as an equity measure, considering service capacity decreasing depending on distance. The paper proposed NSGA-II for solution.

It can be seen that effects of disaster in this area have been addressed using stochastic components usually based on demand, the road network or disruption of facilities, or with GIS to include the geographical dimension of the region. The latter are not really attaining the same level of detail as the former given that every paper using GIS, except for Zhao and Chen (2015), is using the software for data pre-processing, analysis and mapping alone, not really using any capabilities of it to analyse the disaster. On the other hand, the commonality of cost, distance, time and coverage as performance measures is also noticeable. Commonly, the location of supply facilities is based on measures that are not directly considering the level of service provided to the victims.

Finally, no attention is placed on the resources required for opening and managing facilities.

3.3.2 Relief distribution

Relief distribution refers to the dispatch of different commodities to affected areas swiftly and efficiently (Özdamar et al., 2004). This is a crucial factor for high performance response (de la Torre et al., 2012) but at the same time is a very challenging activity faced by response agencies (Horner and Downs, 2007, Sheu, 2007b).

For relief distribution the number of periods accounted for on the model is relevant. Static models can only provide a plan for a single period of time, whereas dynamic models involve a planning horizon divided into several periods.

Focusing on the demand surge of relief items, Arora et al. (2010) studied the static deterministic allocation and redistribution of medical aid focusing on minimising cost associated to the policy selected considering the coordination between regions.

Including the uncertainty of information in terms of supply, demand, road network and facility disruption, Barbarosoğlu and Arda (2004) developed a scenario-based two-stage stochastic programming model for transportation to be used in case of earthquakes. The static multi-commodity, multi-modal network flow formulation seeks the minimisation of total cost. Later on, Davis et al. (2013) also considered uncertainty in supply, demand and possibility of disaster into a static two-stage scenario-based formulation. The first stage is focused on prepositioning decisions whereas the second stage considers distribution incorporating equity of service.

Liu and Zhao (2012) argued that demand for bioterror situations is not really stochastic, but more closely related to the epidemic diffusion rule. The bi-level dynamic model proposed determines how to replenish emergency resources in the upper level, whereas in the lower level how to allocate emergency resources to the infected areas is the problem addressed. The method includes a forecasting model for the time-varying demand and a forecasting model for the time-varying inventory. The objective is to minimise the total rescue cost.

As mentioned before, there is a new trend of dynamic papers suggesting appropriate functions for disaster management supporting single-objective models. Holguín-Veras et al. (2013) based their study on economic welfare to analyse objective functions encompassing the combination of logistics costs and social costs, where the total social cost is equal to the summation of the deprivation costs at discrete time epochs, plus the summation of the deprivation costs for all nodes outstanding at the end of the planning horizon. The problem with the non-lineal non-convex approach is compared to penalty-based models and models focused on the minimisation of unmet demand, showing that the inclusion of social costs can improve the quality of the solutions. Later on, Sheu (2014) performed a comprehensive analysis of the perception–attitude–resilience relationships of survivors for response operations. The article provided a conceptual framework validated using structural equation modelling on questionnaires obtained from central Taiwan. The results are used to identify survivor-specific disaggregate attitudinal functions and design a service-distribution model. The centralised dynamic model aims to maximise the collective resilience of survivors integrated into the minimisation of the logistic distribution cost.

Even with the development of such functions, however, it is very difficult to account for the complexities of relief distribution with a single performance measure. As a result several authors have suggested the use of more objective functions (Ortuño et al., 2011). Huang et al. (2015) presented a dynamic approach accounting for human suffering with three objectives; maximise lifesaving utility, minimise delay cost as a measure of human suffering, and minimise the sum of squares of the distances between the demand fill rates and the ideal demand rate. Lifesaving utility is used as preference of the affected people concerning the relief resources, and the delay cost is similar to the deprivation cost used by other authors. The model is integrated into a time space network and it is solved using the weighted-sum method and an efficient variational inequality algorithm.

The use of multi-objective models is usually related to more common performance measures. Vitoriano et al. (2015) explored and described the value of Intelligent Decision-Making Models for disaster management, stressing the importance of multiple criteria for different operations. Under this umbrella, lexicographic approaches solved using goal programming are quite frequent either being deterministic (Tirado et al., 2014) or stochastic (Ortuño et al., 2011, Liberatore et al., 2014, Sha-lei et al., 2014). Designing a two-phase dynamic flow model, Tirado et al. (2014) analysed the delivery of aid at the first level by minimising the difference between the planned aid to be distributed and the aid sent, dealing on the second level with time, cost and highest unsatisfied demand. Considering ransack probability, Ortuño et al. (2011) developed a static model looking to determine the amount of goods to send and the routes used by a fleet of heterogeneous vehicles. The prior objective is assigned the first priority in the model, and the second priority is then used for the combination of cost to budget, travel time, maximum ransack probability and minimum reliability in links, equitable distribution of goods, and priority status for a singular node. Accounting for damage in the road network and the need for repair for subsequent distribution, Liberatore et al. (2014) presented a static distribution-recovery model for disasters, looking to maximise the total reached demand, minimising the maximum distance from reliability, security and demand satisfaction from its ideal value, and minimise the sum of the attribute distances. Sha-lei et al. (2014) incorporated stochastic demands, reliability of the distribution network and Bayesian updates for disaster scenario information. The aim of the static model is to minimise total time, total unmet demand, and total cost, solved as a fuzzy goal programming (FGP) model.

Considering uncertainty in information, Adıvar and Mert (2010) looked at the coordination of international relief items using fuzzy logic to provide a collection-distribution plan for disaster response. The dynamic model minimises cost and maximises the minimum credibility of international organisations to deliver relief items on time; using credibility as a fuzzy parameter. Incorporating uncertainty of relief demand by using forecasting, clustering and dynamic relief supply to prepare the logistic operations related to distribution, Sheu (2007b) designed a model to maximise the fill rate and minimise the distribution cost, and it is integrated into a unique objective function through the weighted-sum method.

Relief distribution, routing and scheduling

Some articles are incorporating routing a scheduling on the decision-making, including periods as working shifts. Starting with deterministic approaches, Suzuki (2012) showed the implications of fuel availability in the aftermath of a disaster by proposing a static model looking to maximise the minimum per-capita meal availability among all shelters subject to constraints of fuel. Also with a static formulation, Berkoune et al. (2012) took a practical transportation problem including docking times and time needed for loading and unloading one unit aiming to minimise the total transportation duration.

Among dynamic models, Haghani and Oh (1996) designed a multi-commodity, multi-modal network flow model with time windows for large-scale disaster situations based on the concept of a time-space network. The model minimises cost including transhipment nodes and time windows for deliveries, and the authors proposed two algorithms for solution: Lagrangian relaxation and a tailored algorithm. Later on, Özdamar et al. (2004) developed a multi-commodity multi-modal model that indicates the optimal mixed pick-up and delivery schedules for vehicles as well as the optimal quantities and types of loads picked up and delivered on these routes. The goal of the model is to minimise total unsatisfied demand. The authors proposed a Lagrangean relaxation based iterative algorithm for the solution. More recently, De Angelis et al. (2007) developed a real-case oriented multi-depot, multi-vehicle routing and scheduling model for deliveries of food aid by air in Angola based on the operations of the World food Program in 2001. The aim is to maximise the total demand satisfied considering limitations on the supply, assuming the quantity of food sent to the various localities should satisfy some lower bound on the percentage of the quantities calculated for each of the communities.

A very interesting trend encompassing routing for relief distribution and casualty transportation has been developing in this area for a while. The idea is to optimise the use of vehicles by combining the delivery of relief items and the transportation of injured people on the same schedule. Yi and Özdamar (2007) proposed a dynamic two-stage procedure in which the amount of injured people and the flows of relief is determined on the first stage, and routing and scheduling are performed on the second. For the former a multi-commodity network flow model that treats vehicles as integer commodity flows is proposed seeking to minimise the weighted-sum of unsatisfied demand and injured people waiting considering coverage and service level, whereas the latter is obtained using a routing algorithm. Building-up on that, Yi and Kumar (2007) provided an ACO algorithm decomposing the problem in two phases: the vehicle route construction, and the multi-commodity dispatch. The dynamic model proposed is aiming to minimise unsatisfied demand and unserved wounded people waiting for health care services. Focusing on helicopters, Ozdamar (2011) designed a formulation looking to minimise mission time including transportation and load/unload time to obtain the information used on the post-processing stage. Then, the *route management procedure* converts the arc flows into vehicle routes, calculates fuel consumption, determines re-fuelling stops, and constructs the flying itineraries. Later on, Özdamar and Demir (2012) presented a modified static version of the model described in Yi and Özdamar (2007) using a hierarchical ‘‘cluster first, route second’’ approach in which each demand node cluster includes the warehouse and hospital nodes. The aim of the model is to minimise total travel time of vehicles and to promote efficient resource utilization. Incorporating demand and data uncertainty, Najafi et al. (2013) developed a dynamic multi-modal, multi-commodity model for relief distribution and casualty transportation in cases of earthquakes. The model is aiming to minimise the total waiting time of unserved victims, minimise total lead time for commodities, and minimise the total number of vehicles utilized in the response; solving the model lexicographically.

Considering uncertainty on time and demand, Shen et al. (2007) developed a static chance-constrained programming model based on Shen et al. (2009) with split-delivery constraints. The paper considers two-stages: generating the routes in advance of any emergencies, and afterwards to decide the delivery quantity. The authors aim to minimise the combination of unmet demand and arrival time at each node, considering arrival time a secondary objective. The model is solved using a Tabu search heuristic.

Using a penalty-based formulation, Balcik et al. (2008) applied a rolling horizon approach (See Sahin et al., 2013) to determine delivery schedules for vehicles and allocation for resources with the objective of minimising transportation cost. The two-phase modelling model determines the route with the minimum travelling time for each vehicle by solving a TSP on the first phase and then the optimisation model considering the worst-case estimate.

Models with more than one criterion have also been explored. Yan and Shih (2009) studied the relationship between emergency roadway repair and relief distribution in earthquakes, aiming to minimise the length of time required for both activities. The static bi-objective, multi-commodity multiple-modal network flow problem is solved by applying the weighted-sum method and implementing a heuristic. Lin et al. (2011) proposed a dynamic multi-commodity model with three objective functions: minimise penalties related to unsatisfied demand, minimise travel time, and minimise the difference in the satisfaction rate between nodes, considering soft time windows. The authors proposed two strategies for solution: a genetic algorithm or a decomposition and assignment heuristic.

Incorporating the reliability of the path into de analysis, Vitoriano et al. (2011) designed a static goal programming formulation aiming to minimise the deviation of cost, time, equity, priority, reliability and security from the proposed values. Accounting for uncertainty in demand, Tricoire et al. (2012) developed a static multi-modal two-stage stochastic model incorporating minimisation of total cost and uncovered demand to address the problem, optimising both on the first stage and uncovered demand alone on the second stage. They considered a certain percentage of people can decline to go to the nearest DC, and DCs are considered tour stops.

There is an absence of articles incorporating GIS to include the conditions of the disaster in this section, which is tackled by some articles by considering stochastic damage in the road network, uncertain demand and disruption of facilities. Therefore, the potential advantages of the use of these systems for relief distribution are still unexplored. Also, all of this articles are considering pre-defined points for distribution and only including the shipment of items, even though relief distribution is closely related to other activities of disaster management (Caunhye et al., 2012). Distribution is commonly undertaken jointly by several organisations, nevertheless from all the models presented in this section only Arora et al. (2010) and Adıvar and Mert (2010) incorporated this element in the formulation.

3.3.3 Stock prepositioning

The storage of inventory in advance to disaster in strategic locations to enhance relief distribution after the event is called stock prepositioning (Ukkusuri and Yushimito, 2008, Rawls and Turnquist, 2010). This strategy was borrowed from military operations (Akkihal, 2006) with the purpose to increase the efficiency of the supply chain (Richardson et al., 2010) as it reduces lead time (Bozkurt and Duran, 2012, Ukkusuri and Yushimito, 2008),

Standalone stock prepositioning has been studied using stochastic approaches as displayed by Wyk et al. (2011), accounting for uncertainty of the occurrence of the disaster and demand. The paper presented a stochastic model tailored for the conditions of the Southern African Development Community. The model is a multi-commodity static variant of Taskin and Lodree Jr (2010), and it seeks to minimise the total expected cost. Lodree Jr et al. (2012) presented a two-stage stochastic programming model for hurricanes based on the idea of vendor management inventory (VMI). Supplies are prepositioned on the first stage and sent to retailers to satisfy the need of relief items on the second stage.

The use of multi-objective models has also been considered for stock prepositioning. Belardo et al. (1984) developed a model for sitting special spill response equipment prior to an event using a set covering approach. The multi-commodity model aims to maximise coverage across different urgency probabilities including both assessments of the relative probability of occurrence and the impact after occurrence of various spill types. The three probability functions are combined using the weighted-sum method for solution.

Despite of the great advantages provided by stock pre-positioning, this policy can result on very high costs and the uncertainty of events can affect perishable items. As a result, there are articles exploring alternative solutions. Oloruntoba and Gray (2006) argued that the use of effective demand-led inventory management using postponement can allow quick responsiveness while maintaining lowers cost in comparison to prepositioning. Later on, Saputra et al. (2015) explored the trade-off between transport modes and end-of-shelf-life policies for medicine prepositioning in cases of disaster. Using the operations of Médecins Sans Frontières in Zimbabwe, the authors concluded that if the mean time between disasters is smaller than the actual remaining shelf-life of stocked items, then most likely the resources will be used before expiry. Kunz et al. (2014) also argued the feasibility of stock prepositioning by analysing the differences between that strategy and investing in disaster management capabilities. These capabilities include training staff, pre-negotiating customs agreements, or harmonizing import procedures with local customs. The paper used system dynamics to represent the process including time delays as a relevant factor and considering nonlinear functions. Using data from the 2011 Horn of Africa crisis, the article showed the importance of applying a preparedness strategy, the high-level of service and high-cost relationship inherent of prepositioning, and the potential of investing in disaster management capabilities with good levels of service and lower costs than stock prepositioning.

Stock prepositioning is a common and valuable strategy, but high costs are a real possibility using this approach. The inclusion of stochastic components related to demand and the event are expected, but these may be insufficient given the possible disruption of facilities. Even so, there are no articles in this section including neither the geographical dimension of disaster nor the joint participation of different organisations.

3.3.4 Inventory management

Inventory management includes the estimation of re-order point, batch size and the level of safety stock (Falasca and Zobel, 2011). This activity differs from stock prepositioning because it is performed on the response phase (Caunhye et al., 2012) for the duration of the whole emergency situation. After natural catastrophes, having available relief items and dispatching them swiftly is more important than having low stock levels (Long and Wood, 1995).

Developing a stochastic inventory control model (SICM) for NGOs, Beamon and Kotleba (2006b) incorporated multiple suppliers, the existence of normal and emergency orders, and a coefficient of stock-out risk into a continuous review inventory system to obtain the batch size, re-order point, cycle length, number of backorders and total cost for a single item. An application of the model on Kenya with information gathered from World Vision International is presented on Beamon and Kotleba (2006a), comparing the performance of a Silver-Meal heuristic against setting the re-order level equal to the expected number of items to be requested to have a continuous schedule. The results on a simulation model built on Arena® showed that the model allowed more flexibility, provided more robust solutions and reduced response time, at a cost of large order quantities. Also designing a SICM, Ozbay and Ozguven (2007) focused on safety inventory to avoid service disruption based on the Hungarian Inventory control Model. The two-stage multi-commodity model considers delivery and consumption processes stochastically independent, aiming to minimise total cost. The solution of the nonlinear model is proposed through the use of p-level efficient points method. Later on, Taskin and Lodree Jr (2010) designed a SICM for private companies considering predictions associated with the ensuing hurricane's season demand distribution according to a Markov chain. The model aims to minimise cost and it is solved through the simultaneous backward reduction algorithm. Using a Bayesian decision framework instead, Taskin and Lodree Jr (2011) provided an inventory management model to determine the optimal production quantity aiming to minimise the expected loss associated with production, overstocking and under stocking. More recently, Das and Hanaoka (2014) developed a SICM based on a first-order differential equations considering a continuous inventory review strategy and uniformly distributed relief demand. The method proposed is embedding stochastic lead-time and demand into an algorithm for a multi-commodity inventory model aiming to minimise the expected total cost.

Considering uncertainty with known demand distributions a priori, Lodree Jr and Taskin (2008) provided a framework using four variants from the newsvendor problem seeking to minimise cost to decide whether to invest or not to invest in an inventory policy for disasters. Accounting for uncertainty in the occurrence of the event, Lodree Jr (2011) provided an inventory policy based on an EOQ framework to reduce cost for retailers under the possibility of storms. The policy determines if the local retailer should pre-order additional inventory, or wait until a demand surge scenario has been observed to order inventory.

The models presented in this section are completely focused on the minimisation of cost, seeking to satisfy demand generated by disasters. It is important to notice the use of one performance measure and, although the attention centred on the identification of disaster predictions, GIS is not used at all in this area.

There is a focus on one decision-maker, even though disaster situations are characterised by the high number of actors (Nolte et al., 2012). That has been identified by practitioners, providing solutions as the inventory and tracking system for humanitarian supplies (SUMA) aiming to manage a scenario of uncoordinated donations (PAHO, 2015).

3.3.5 Resource allocation

Relief items are only one kind of resources required for disaster management, and the study of the allocation of other resources for successful operations such as people (Thompson, 2015), vehicles (Balcik et al., 2010) and equipment (Sha-lei et al., 2014) is necessary. Resource allocation models determine the assignment of emergency security and relief resources before or after the disaster (Hoyos et al., 2015, Safeer et al., 2014, Sha-lei et al., 2014). These kind of models allow pooling resources from different actors, which in turn can prove effective for disaster operations (Balcik et al., 2010).

There are a number of papers using one performance measure for the allocation of teams or units with static models. **Brown and Vassiliou (1993b)** divided the activities performed by armed forces in two sections: tactical and operational. For the operational decisions, the system includes two models focused on minimising the distance cost of the solutions depending on the desire of considering or disregarding team relocation. For the tactical decisions, another model is used to allocate resources to the tasks assigned to each unit by seeking to maximise efficiency in terms of the appropriateness of the team for the task. Wex et al. (2014) provided a decision support model to schedule rescue units and assign them to incidents optimally. The formulation seeks to minimise the weighted sum of completion times over all incidents for a set of rescue units with different capabilities and it is solved using 40 composed heuristics based on greedy algorithms, construction algorithms, improvement algorithms and GRASP algorithms, along with a Monte Carlo algorithm. Incorporating risk, Sherali et al. (2004) developed a model aiming to minimise the overall system weighted risk and inequity related to the allocation. The authors presented a branch-and-bound algorithm to solve the model. Considering secondary disasters, Zhang et al. (2012) proposed a unit resource assignment method for disaster relief. The model aims to minimise travel time from supply points to the primary affected area and from the supply points to the secondary affected areas considering individual probabilities of the occurrence of secondary disasters. The model is solved using local search techniques with high-possibility high-priority rule. Incorporating a deterministic multi-objective approach, Falasca and Zobel (2012) focused on the scheduling problem for volunteer assignments under disaster conditions. The authors proposed a bi-criteria static optimisation model aiming to minimise task shortage costs and number of undesired assignments by volunteers to particular time blocks and locations. The authors proposed two solution approaches: the first considering the efficient frontier approach and another using a fuzzy approach by representing objectives as membership functions with different levels of urgency. The former included a comparison between the weighted-sum method, goal programming and generation of the efficient frontier. More recently, Altay (2013) developed a static model to allocate response personnel, facilities, supplies and equipment to disaster-affected jurisdictions. The situation becomes a matching problem with two alternative objective functions: to minimise total deployment time or minimise maximum response time. For shortages the paper introduces a multi-objective optimisation model looking to minimise the weighted-sum of total deployment time and total capability deficit.

Looking at rescue activities, Barbarosoglu et al. (2002) addressed helicopter missions involving the coordination between different bases. The problem is decomposed hierarchically into two sub-problems where the top level determines the helicopter fleet, pilot assignments and the total number of tours, whereas the base level addresses the vehicle routing of helicopters from the operation base to disaster points, the load/unload, delivery, transhipment and rescue plans of each helicopter in each tour, and the re-fuelling schedule of each helicopter given the solution of the top level. The top level aims to minimise the combination of distance to the base, class of pilot and the operational cost, while the base level tries to minimise makespan. Later on, Yang et al. (2013) provided a dynamic optimisation model aiming to maximise the overall emergency rescue effectiveness of allocated resources and minimise the allocating costs of resources. The model is proposed to be solved by the ideal point method.

Exploring the allocation of support equipment with static approaches, Chen et al. (2011) developed a GIS based framework integrated by an Emergency Resource Repository Portal (ERRP), Mobile Resource Request Client (MRRC), and Automate Resource Management System (ARMS). The ERRP is a geospatial database, whereas the MRRC is a mobile application which provides on-field first responders with digital resource requests and the ARMS is a GIS which produces routes to disaster sites from multiple resource locations built using ArcGIS. The deterministic model proposed aims to minimise the total travel time for the delivery of equipment. Undertaking a scenario-based approach, Chang et al. (2007) designed a multi-group, multi-echelon, and multi-level structure planning tool considering the use of GIS and two optimisation models with different levels of the organisation for floods. Vector GIS is used to apply data processing and network analysis to obtain demands through flooding potential maps, along with shortest-path analysis. The first stochastic model is a grouping and classify model to determine clusters of demand aiming to minimise the expected shipping distance of rescue equipment. Afterwards, a two-stage stochastic model determines local rescue bases in the first stage and the quantity of rescue equipment and transportation plans in the second stage. The model is seeking to minimise the total cost, using the sample average approximation (SAA) scheme as solution method. Including uncertainty in the road network, Edrissi et al. (2013) presented a formulation to coordinate agencies considering strengthening structures of vulnerable areas, retrofitting transportation links and locating and equipping emergency response centres. The multi-agent model addresses the three sub-problems individually aiming to unify the objective function of the different actors to maximise survival rates. Finally, they present a dynamic version of the preparedness optimisation model to ship relief aid in the response stage.

This section contains a wider variety of objectives used compared to other activities, and most of them are oriented towards the provision or accomplishment of services. Cost and time are still very common objectives, though. Coordination of different participants appears as an inherent factor for several of the papers, demonstrating the importance to handle different resources appropriately beyond relief items. However, none of the models has the capability to optimise the number of organisations involved. Finally, there is a predominance of static models over dynamic models, even though allocation can vary through time according to the needs presented by the situation.

3.3.6 Location of supply facilities and stock prepositioning

From this point onward the articles reviewed are combining different decisions under the same umbrella, seeking a more integrated approach for disaster management. The location of supply facilities and stock prepositioning is a very natural synergy, focusing on two main activities for preparedness. Undertaking a deterministic approach, Akkihal (2006) developed four optimisation models for location and prepositioning decisions based on the p-median problem. The models are aiming to minimise the average distance travelled per affected person, and each model is solved using a distance sensitivity algorithm.

Incorporating scenarios into the formulation, Jomon Aliyas and Hariharan (2012) developed a framework to position relief from the Strategic National Stockpile to deliver medicines to hospitals in cases of disaster. The first step uses FEMA HAZUS-MH to simulate scenarios, and simultaneously potential locations of stockpiles are determined. Then, the demand is grouped in clusters, and next the model is used to establish locations and capacities of stockpiles by minimising the social cost in terms of stockpiling cost and fatality cost. Finally, the mini-max regret decision making rule is used to determine the policy. Balcik and Beamon (2008) presented a model based on the MCLP looking to maximise the demand attended by distribution centres considering the probability of occurrence of the disaster and the level of coverage. More recently, Duran et al. (2011) studied the location of global distribution centres and stockpiles for CARE International considering multiple disasters. The authors designed an inventory-location model seeking to minimise the average response time, constraining the solution to the inventory amount to keep in the network. Building upon that, Bozkurt and Duran (2012) used the same model to expand the warehouse network of CARE International and to determine the level of stock prepositioned, suggesting a fourth warehouse in Kenya.

Campbell and Jones (2011) incorporated risk of facility disruption for one supply point using equations aiming to determine the optimal stock quantity and the total expected cost associated with deliveries, with an alternative for multiple supply points. Galindo and Batta (2013a) accounted for possible destruction of supply points during the disaster event by increasing a percentage of the supplies prepositioned (i.e. safety stock) with amplifying factors. The single commodity model seeks to minimise total expected cost including deliveries and cost of units destroyed.

It is important to mention that all the articles included in this part used a static perspective, as expected by the nature of the problems studied. Among the drawbacks, even though the potential benefits for sharing resources have been stated in the literature, none of the articles mentioned incorporated the participation of different organisations.

On the other hand, although location is closely related to geographical factors and several articles are using different probabilities of risk or disruption for scenarios, only Jomon Aliyas and Hariharan (2012) included the value of the physical impact of disaster.

3.3.7 Location of supply facilities and relief distribution

Görmez et al. (2011) proposed a two-stage optimisation model considering a two-tier distribution system. In the first stage, the temporary facilities are located minimising the demand-weighted distance. Then, the supply from existent to new facilities is addressed by a bi-objective model seeking to minimise the average distance travelled to serve a refugee and the number of new facilities to establish, solved with the e-constraint method.

Merging location, distribution and routing with a dynamic formulation, Afshar and Haghani (2012) designed a multi-commodity, multi-modal model based on FEMA's logistic structure with the objective of minimising total unsatisfied demand for disaster victims. Lin et al. (2012) used a penalty-based multi-commodity approach, minimising the cost of penalties for unsatisfied demand, delayed delivery and service unfairness. The cost of penalties is added to travel cost. The model is solved through a two phase heuristic to locate temporary depots and allocate covered demand points in Phase I, and to explore the best logistics performance in Phase II. Tackling uncertainty in demand by using fuzzy numbers and undertaking a multi-objective approach, Shuang-lin et al. (2011) designed a static multi-modal model seeking to minimise total travel time and the system loss due to unsatisfied demand. The model is solved using the NSGA-II algorithm. Conversely, Barzinpour et al. (2014) developed a dynamic bi-objective multi-commodity model seeking to determine DCs to be activated along with service allocation by minimising total cost and maximising the aggregated percentage of items for service level simultaneously. The authors used the multipurpose linear programming approach to obtain a single-objective solution problem to solve through a genetic algorithm and a simulated annealing algorithm.

The state of the road network after disaster is of paramount importance for location and distribution, as shown by Horner and Widener (2011). Assessing the impact of simulated network failures on hurricane disaster relief planning strategies in Florida City, they showed that modest disruptions to the transportation network produce marked changes in the number and spatial configuration of relief facilities. In line with these findings, Verma and Gaukler (2014) developed a static deterministic and a static stochastic model. The former aims to minimise the expected transportation cost over all instances, whereas the latter accounts for damage intensity as a random variable to select facilities on the first stage and the distribution decisions on the second stage. The authors proposed a modified L-shaped method to optimise a Sampling Average Approximation for the stochastic model.

Using scenarios to consider uncertainty in demand and the probability of occurrence of the event, Liu and Guo (2014) developed a static multi-commodity model for response operations focused on location of facilities, delivery plans for relief distribution, allocation of personnel and mobilisation plans for evacuees using helicopters. The multi-commodity model is aiming to maximise the expected minimal fill rate of affected areas and minimise total cost. Considering the importance of the first objective compared to the second-one, a lexicographic approach was proposed.

Exploring the use of GIS for network analysis, Horner and Downs (2010) built upon Horner and Downs (2007) by including capacities in the static formulation to provide a GIS-based model aiming to minimise costs of distributing relief goods. Adding multi-objective programming and uncertainty to the mix, Tzeng et al. (2007) provided a fuzzy dynamic model encompassing the distribution from suppliers to customers passing through distribution centres. The three-objective model aims to minimise total cost, total travel time, and maximise the minimal satisfaction during the planning period. TransCAD® was used to identify the shortest routes and alternatives. For the solution the authors proposed the use of fuzzy multi-objective linear programming.

Facility location and routing

There are a number of studies addressing the location of supply facilities along with routing alone. Liu et al. (2012) developed a method based on the use of Grey theory to establish an evaluation system of emergency supply routes in cases of disaster. The method includes an assessment of factors such as cost, travel time, road conditions, among others to evaluate a set of pre-defined routes aiming to minimise the number of distribution centres needed.

Using optimisation with a deterministic perspective, Zhang and Yan (2008) developed a method accounting for the risk of bottleneck of the distribution network and the location risk. The static model looks to minimise total cost and the authors proposed a polynomial algorithm based on Dijkstra's algorithm to solve the problem. Naji-Azimi et al. (2012)

provided a static model with the objective of minimising the total distance travelled by a heterogeneous fleet, solved with a 3-step heuristic: pre-processing, initialization and local search. Proposing a dynamic approach, Han et al. (2007) designed a multi-commodity model for warehouse selection/construction, scheduling and routing aiming to minimise total transportation cost.

Incorporating uncertainty in the transportation network, Ukkusuri and Yushimito (2008) developed a static method to determine the selection of locations for prepositioning humanitarian supplies and the routing strategy. The authors used a combination of the most reliable path and a model extended from Berger's formulation. The objective of the model is to maximise the reliability of reaching a demand point.

Han et al. (2010) extended Han et al. (2007) by incorporating uncertain demands and allowing the minimisation of cost to be substituted by distance or time. It is solved using p-efficient points to derive an equivalent deterministic model. Later on, Han et al. (2011) added delivery deadlines, the amount of items to store and route capacity to the formulation. The authors provided a successive sub-problem solving-based method in Lagrangian relaxation.

Incorporating the probability of the disaster into a static model, Mingang et al. (2009) developed a method broken-down into two sub-problems: the emergency facilities location problem and the emergency resource routing problem, using the clustering method to solve the former and ACO to solve the latter aiming to minimise total cost. Xinhua (2012) developed a model to determine the optimal distribution path considering probability of risk in the supply chain introducing the construction of intermediate facilities. The model considers a M/M/c/k (i.e. Multiserver, Finite-Capacity System with *k* customers) queuing system and uses the penalty function method to determine the delays. The nonlinear problem is looking to minimise a combination of cost and time, and it is solved with a genetic algorithm.

Using a deterministic perspective with multiple objectives, Rath and Gutjahr (2011) provided a method for international aid organisations focused on medium-term relief. The static model aims to minimise opening and operations costs, transportation cost and maximise covered demand. The authors proposed two solutions: the adaptive ε-constraint method and a math-heuristic technique. Later on, Wang et al. (2014) developed a static nonlinear model considering the possibility for successfully travelling through the available links known a priori. The model aims to minimise the maximum vehicle route travelling time, distribution cost and maximise route reliability. For solution, the authors proposed the use of NSGA-II.

Looking into the disruption of connectivity for routes, Nolz et al. (2011) presented 5 approaches to manage risk for floods and earthquakes within one objective function. The static model encompasses three objective functions: minimisation of risk, distance and total travel time. The model is solved in two phases: applying a memetic algorithm including a variable neighbourhood search and path relinking for the first phase, and using Martin's algorithm to compute all combination of paths included in the potentially Pareto-optimal solutions.

Adding the advantages of GIS with single objective optimisation, Ahmadi et al. (2015) included real-time data on the actual transportation network condition, incorporating the possibility of road destruction under various earthquake scenarios. They proposed a static two-stage stochastic multi-commodity model with random travel time considerations seeking to minimise a combination of travel time, penalty costs for unsatisfied demand, location cost, penalties for violation of the standard relief time and the expected total distribution time, solved with a variable neighbourhood search algorithm.

The split in the number of articles considering or disregarding routing is important to highlight. Vehicle Routing Problems (VRPs) are very well known NP-hard problems, thus the reluctance of several authors to include routing along with location and distribution. The uncertainty associated with the road network and knowledge from local personnel can play a big role in this activity.

Also there is a split in the number of static and dynamic models for facility location and distribution, whereas only static models were described for facility location and routing. This was unexpected as location is usually performed once whereas distribution and routing are ongoing processes. Looking at the papers tackling location and distribution, most of the articles are using more than one performance measure in comparison to single-objective models, portraying the suitability of this approach for the combination of different activities and supporting the reluctance of several authors to add VRP to the mix.

Discussing the performance measures, it can be concluded that articles focused on routing are tending to time, cost and distance, whereas articles looking at the distribution policy are also including fill rate and demand satisfaction. The scant use of GIS is also remarkable among the articles presented, being the application to network analysis the only dimension explored for GIS on this area. Also, there are not considerations to human resources required to manage neither the facilities nor the participation of different actors.

3.3.8 Facility location, stock prepositioning and relief distribution.

The final combination studied on this review is related to the synergy between facility location, stock prepositioning and relief distribution. The strong link between these activities is apparent given the number of papers in this part, showing the communion between preparedness and response.

Undertaking a static deterministic approach, Rekik et al. (2011) provided a 3-step algorithm designed to find the minimum number of facilities to open in the first step, determine the location of them by maximising coverage in the second, and to establish the quantity of resources allocated at each facility by minimising uncovered demand on the final step.

Proposing a static chance-constrained model, Murali et al. (2012) accounted for demand uncertainty. The model aims to maximise the number of people served understanding demand dependent on the distance between the distribution facility and the demand area with multiple coverage levels. The solution proposed is a locate-allocate heuristic (Jia et al., 2007b) initialised by the results of a greedy approach. Also incorporating demand uncertainty, Lejeune (2013) proposed a set of stochastic service level constraints for the fill rate, ready rate, and conditional expected stock out dynamic service level policies. The multi-commodity model aims to minimise total cost. Using a static multi-commodity scenario-based formulation to account for uncertainty in supply, demand, transportation and procurement, Bozorgi-Amiri et al. (2012) proposed a nonlinear model aiming to minimise the sum of the expected total cost and the variance of it. The method is based on scenarios with probability of occurrence and the robust optimisation model is based on Mulvey's model. The solution is obtained with a PSO heuristic.

Using a scenario-based formulation, Renkli and Duran (2015) based on the uncapacitated location problem supplemented by chance constraints to consider uncertainty in the damage to the road network. The static multi-commodity model aims to minimise the weighted probability of road blockage.

There are a large number of papers considering two-stage stochastic static optimisation models with scenario-based approaches. Klibi et al. (2013) used a scenario-based approach into a three-phase procedure to account for uncertain demand and unreliable network information. The first phase uses a Monte Carlo procedure to determine a set of scenarios, whereas the second phase solves the two-stage stochastic model and the third phase evaluates and compares the results. Regarding the model, the first stage aims to minimise the expected cost of the second stage weighted by its probability of occurrence, whilst the second stage is seeking to minimise the total penalty associated to satisfying demands within higher covering levels. The solution of the model is proposed using the SAA method. Similarly, Döyen et al. (2012) proposed a multi-commodity model solved through a heuristic method based on Lagrangean relaxation. The model introduces the location of local and regional facilities, and it aims to minimise the total cost of the system. Considering uncertainty on demand, road network and conditions after disaster, Salmeron and Apte (2010) provided a multi-modal formulation to determine a plan focused on cyclic disasters aiming to minimise the expected number of casualties and the expected unmet transfer population. The model determines the location and expansion of resources at the first stage and the deployment of resources at the second one. Incorporating also the possibility of destruction of relief, Rawls and Turnquist (2006) developed a multi-commodity model aiming to minimise total expected cost, solved using the integer L-shaped method. Rawls and Turnquist (2010) supplemented Rawls and Turnquist (2006) by incorporating unmet demand penalties and holding costs for unused material. Building upon that, Rawls and Turnquist (2011) added of service quality constraints, considering reliability by ensuring the probability of meeting all demand as at least α. Complementing that by incorporating a risk measure on total cost, Noyan (2012) explored the use of a risk-averse approach and developed two algorithms based on Benders-decomposition for the solution. Also using a risk-averse approach, Hong et al. (2015) developed a probabilistically constrained model considering the uncertainty in the road network. In the first stage the objective is to minimise location cost, procurement cost and expected cost of the second stage, whereas the second stage is focused on minimising shortages, surplus and transportation costs. The solution method proposed uses a pre-processing algorithm and a method based on combinatorial patterns to obtain MIP formulations. Rawls and Turnquist (2012) extended the work of Rawls and Turnquist (2010) by developing a dynamic variant of the model focused on the arrival of affected people to shelters over time, considering the first 72 hours after the disaster strike. The purpose is to improve the supply distribution pattern for a set of multiple periods. Incorporating location, prepositioning, distribution and routing under the same umbrella, and dealing with uncertainties by using a scenario-based approach, Mete and Zabinsky (2010) designed a static model in which the first stage determines the location of warehouses and amount of prepositioned stock by minimising cost, whereas in the second stage a combination between weighted transportation time and unsatisfied demand is minimised to determine the amount of medical supplies to deliver and the selection of routes based on pre-determined plans. Later on, Rennemo et al. (2014) considered the number of vehicles available for transportation, the state of the infrastructure and the demand of the potential beneficiaries as stochastic elements, pursuing fairness by prioritising urgent demand in a dynamic formulation. The objective function across stages is to maximise the combination of demand fulfilment and unused budget.

Adopting deterministic multi-objective optimisation, Abounacer et al. (2014) proposed a static model to determine the number, the position and mission of required humanitarian aid distribution centres, along with inventory levels, distribution of aid and routing. The model is solved through a variation of the ε-constrained method. The objectives of the model are to minimise transportation time, number of personnel needed and uncovered demand. This paper emphasises the importance of personnel considerations, docking times and a maximum daily work time.

Accounting for uncertainty also with static multi-objective approaches, Gunnec and Salman (2007) developed a two-stage multi-criteria stochastic model based on the use of goal programming considering probability of failure in the road network and different scenarios to determine demand after disaster. The facility locations, capacities and inventory levels are determined in the first stage and in the second stage the distribution plan is established. The objective is to minimise total expected weighted time to transport all commodities, supplemented by the minimisation of the average risk associated with the locations, total expected weighted unsatisfied demand and the sum of costs. Bozorgi-Amiri et al. (2011) proposed a scenario-based multi-commodity model incorporating uncertainty not only in demand, but also in supply and in the cost of procurement and transportation, along with the possibility that prepositioned supplies might be partially destroyed by the disaster by using backup facilities. The model consists of two-stages; the first stage determines the location of distribution centres and required inventory, and the second stage determines the amount of relief to deliver. The model involves two objective functions, aiming to minimise the sum of the expected value and the variance of the total cost of the relief chain simultaneously with minimising the sum of the maximum shortages in the affected areas. The solution method is based on compromise programming.

Geographical analysis has also been used for static approaches in the literature. Barzinpour and Esmaeili (2014) presented a two-echelon disaster supply chain for relief items and equipment. They consider the importance of the features of disaster by using the Risk Assessment tool for Diagnosis of Urban Areas against Seismic Disaster (RADIUS) to obtain the parameters for different earthquake scenarios. The formulation includes three objective functions seeking to maximise coverage, minimise location costs and minimising operational costs. The solution is obtained using a goal programming approach. Extending that by considering coverage outside of the region, Esmaeili and Barzinpour (2014) incorporated three objectives including the maximisation of coverage in the municipal area, but with the difference that the second objective function minimises the sum of all costs and the third one maximises coverage outside of the municipal area. The model is solved using a genetic algorithm.

A novel approach exploring the location of both shelters and distribution centres on the same method was provided by Rodríguez-Espíndola and Gaytán (2015), who developed a methodology for flood preparedness including a GIS analysis to discard floodable facilities and identify road failures. The model seeks to minimise total cost and total distance travelled considering priorities for the most affected areas. The multi-commodity multi-modal model is solved using a combination of the weighted-sum method and the ε-constraint method.

The strong dominance of static models is clear in this section, showing that this approach is mostly used to provide support for the distribution of prepositioned items after the disaster, leaving the posterior distribution to other methods. The objectives used are somehow diversified but still within the parameters of common performance measures. The use of stochastic models is something to highlight, and it is because the combination of location, propositioning and distribution implies uncertainty on demand, road network and supply.

This work is building upon Rodríguez-Espíndola and Gaytán (2015) in the sense that this research is also considering the location of both shelters and distribution centres, along with the use of raster GIS. However, the preparedness model designed here differs from the one of Rodríguez-Espíndola and Gaytán (2015) in the use of a novel performance measure based on the provision of time and services in shelters, the orientation towards resource allocation and accounting for the participation of several agencies by optimising the number of actors involved, along with the extension towards response portrayed by the second model proposed.

3.3.9 Research gap

This chapter has introduced the most relevant articles related to the topics under study to identify the main approaches used and place the contribution of this research. Of foremost importance is the multi-organisational perspective adopted by this research. This idea contradicts the underlying assumption of one decision-maker from most of the articles presented. It is important to develop methods to allow the coordinated optimisation of different activities (Liberatore et al., 2014) which in turn can derive on better use of pooled resources (Balcik et al., 2010). For instance, the UN is increasingly using warehouse capacity sharing to improve operations (Bozkurt and Duran, 2012).

In the literature there is only a handful of papers are considering the importance of coordinating resources, whether between teams (Altay, 2013, Barbarosoglu et al., 2002, Brown and Vassiliou, 1993a), regions (Arora et al., 2010), organisations (Adıvar and Mert, 2010) or other agents (Edrissi et al., 2013). Also, there are some articles using hierarchical (Tzong-Heng et al., 2011) or multi-group models (Chang et al., 2007) to enhance collaboration, however currently there is no paper optimising the number of actors involved nor disaggregating resources from different agencies for cooperative facilities (See Davis et al., 2013) and operations.

The close correlation between different activities for emergency logistics has been highlighted above, but there is no article tackling facility location, stock prepositioning, resource allocation, and relief distribution under the same umbrella. This dissertation proposes a model for preparedness and another for response to maintain consistency in terms of design and objectives. The purpose is to attain an integrated approach not found on the literature before.

The focus on either evacuation or distribution is creating a disconnection between supply and demand. The location of shelters and the location of distribution centres directly affect the performance of the distribution network. A commonly reported complaint in shelters is the delay on relief delivery (See ACAPS, 2012, CEOC, 2010, López Tagle and Santana Nazarit, 2011, PAHO, 2010) and shortages of supplies (ADB et al., 2010, Dudley, 2007, PAHO, 2010, Santos-Reyes et al., 2010, UNHCR, 2012). Nevertheless, only Rodríguez-Espíndola and Gaytán (2015) explores the location of both facilities simultaneously.

The complex environment surrounding disaster planning is being tackled in the literature using stochastic modelling, hydrologic analysis and GIS. Stochastic modelling considers uncertainty in supply, demand, disruption of facilities and disruption in the road network. Hydrologic analysis is incorporating the physical evolution of the flood, whereas GIS is mostly used for mapping and scenario analysis. The complexity associated with stochastic modelling is portrayed by the low number of articles found using that approach along with multi-objective optimisation. GIS would be expected to play a bigger role to complement optimisation models given its capabilities and its convenience to support the optimisation process. However, most articles in the literature are only using it for data pre-processing, network analysis and data display.

The number of objectives is a relevant aspect, as the articles using more than one performance measure are a minority, but the number is increasing notably in recent years, pointing out the multi-objective nature of disaster management. Also important is the type of objectives. Cost, time, distance and coverage are very commonly considered depending on the activity, but the new trend of 'social cost' functions is creating awareness of the need of considering performance measures linked more closely to the nature of disaster management.

The purpose of this research is to provide a system that can tackle the shortcomings mentioned above. The system designed uses a cartographic model to account for the geographical dimension of the flood, and optimisation to support decision-making. The system is aiming to provide support cutting across preparedness and response, integrating facility location of shelters and distribution centres, stock pre-positioning, resource allocation and relief distribution. Moreover, the models are seeking to incorporate several actors to identify the optimal combination of organisations required and the use of their resources, an approach never undertaken before. Multi-objective optimisation is the approach undertaken to provide a balance between efficiency and effectiveness (See Beamon and Balcik, 2008) with a novel performance measure based on the products and services provided on shelters.

3.4 Mexican disaster management framework

This section is briefly presenting the definition of the National Civil Protection System (SINAPROC from its initials in Spanish), relevant regulations related to disaster management, the structure of SINAPROC, actors involved in logistical operations and the response process to disaster.

3.4.1 National Civil Protection System

Following the impact of the 1985 earthquake in Mexico killing nearly 10,000 people (Alexander, 2015), in 1986 the SINAPROC was created to provide support in cases of disaster. SINAPROC is "*an organic and articulated set of structures, functional relationships, methods, and procedures established by governmental organisations with other public, social, and private sectors, as well as with federal, state, and municipal authorities in order to perform coordinated operations aiming to provide protection against dangers and risks faced by society in cases of disaster*"(SINAPROC, 2015b). It is the structure in charge of performing every possible task to reduce the impact created by disasters (Zepeda and González, 2001).

Decision-making in disaster situations in Mexico is centralised, portraying the role of SINAPROC as a coordinator to articulate these activities from different participants (Sosa-Rodríguez, 2006). The foundations of SINAPROC rely on a group of regulations, from which the most relevant ones are displayed on Table 3.2. These regulations determine the function, capabilities and jurisdiction of SINAPROC. Within the regulations, the guidelines for disaster management are disaggregated by type of disaster as the activities are disaster-specific (See Comisión_Nacional_de_Reconstrucción, 1986, SEGOB, 2006b)

Table 3.2. Civil protection regulations

Regulation	Year
Civil protection general law	2012
Climate change general law	2012
Regulation of the civil protection general law	2014
Agreement to issue the Operation and Organisation Manual for the National Civil Protection System	2006
Agreement to establish the Civil Protection General Coordination as a national security authority	2009
Foundations for the establishment of the National Civil Protection system	1986

Source: Compiled by author with information from SINAPROC (2015a)

3.4.2 SINAPROC structure

Disaster management in the country is performed by four main branches: executive coordination, technical coordination, technical support and co-responsibility. The Ministry of Interior is the entity responsible for managing the executive coordination in cases of disaster, involved with organisations on the three government levels (viz. National, State and Municipal). The technical coordination refers to organisations with the capability and attributions to provide technical counsel for the planning, operation and assessment of the activities related to disaster management, whereas technical support refers to the organisations with capabilities to provide specific aid and advice for one or several disasters. Co-responsibility refers to the organisations charged with the responsibilities to provide supplementary support along with human and material resources to the emergency activities on top of their normal duties (SEGOB, 2006b).

Table 3.3 shows the responsibility matrix derived from SINAPROC regulations for hydro-meteorological disasters.

Table 3.3. Agencies involved in SINAPROC for a hydro-meteorological disaster

Branch	Organisation
Executive coordination	• Ministry of Interior
Technical coordination	• Ministry of Environment and Natural Resources • National Water Commission • Local and state governments
Technical support	• Disaster Prevention National Centre
Co-responsibility	• Ministry of External Affairs • National Defence Secretariat • Ministry of the Navy • Ministry of Treasury and Public Credit • Ministry of Social Development • Ministry of Agriculture, Livestock, Rural Development, Fishing and Food • Ministry of Economy • Ministry of Education • Ministry of Health • Ministry of the Agrarian Reform • Ministry of Tourism • Ministry of Communication and Transportation • Ministry of Security • National Oil Company (PEMEX) • Federal Electric Commission • Airports and complementary services • National Autonomous University of Mexico • Social Health Mexican Institute • Social Health Institute for the Governmental Worker • Mexican Red Cross • National Transformation Industry Chamber • National radio and television chamber • Mexican federation of radio experimenters

Source: Elaborated with information from SEGOB (2006b)

The table above displays the large number of participants involved in disaster management in Mexico, stressing the need for effective coordination in order to accomplish successful operations. It is important to mention that each agency have a set of regulations regarding disaster response, from which the prominent role of the military on disaster management in México (Alexander, 2015) highlights the importance of Plan DN-III and Plan Marina as major references.

3.4.3 Disaster response procedure

After a disaster strikes a community, the first agency at site should provide aid to the victims, and then local authorities can take over to continue the relief activities. If local authorities can cope with the impact of the disaster they oversee the whole operation, otherwise they have to notify state authorities to ask for support. That procedure repeats for the case of state and federal authorities, until the full resources of SINAPROC are deployed (SEGOB, 2006b), as shown by Figure 3.1.

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Figure 3.1. Process of governmental response in disaster situations

It can be inferred that the purpose of the process is to use only the resources necessary for each event. However, activating one stratum means activating a large number of agencies, something that can be further improved to make more efficient use of resources.

3.4.4 Natural disaster fund (FONDEN)

FONDEN is a federal government fund available for agencies from the three levels of government to swiftly acquire financial resources necessary for disaster response and recovery (Saldana-Zorrilla, 2015). Created in 1996, recently it has been established to receive at least 0.4 percent of the Federal budget (World_Bank, 2012). For the use of resources from FONDEN's revolving fund, the State Government should submit a request to declare the situation a national emergency and ensure that the financial capability of the State has been surpassed. After review and confirmation of the request, the Federal Government can declare the emergency and allow access to the resources from FONDEN. (CONAGUA, 2011).

The emergency declaration entitles State authorities to request relief obtained through FONDEN, stating which and how many items from the list of authorised items are required depending on the population affected. Consumable goods are arranged in kits to last four days, thus requests for these items can be submitted every four days until the end of the emergency.

For the case of medicine requests, these should be submitted through the National Centre for preventive planning and disease control, namely CENAPRECE, (SEGOB, 2012).

3.4.5 Gap in practice

This section has introduced some of the main components of the disaster management policy in México. SINAPROC works as a coordinator of a large number of agencies to cope with disaster, making decisions and using resources from these agencies to accomplish the results. It is important to bear in mind the large number of agencies involved from different levels of government, most of them providing human and material resources to provide assistance to disaster victims.

A clear group of regulations and well-placed financial instruments are evidence of the importance and the weight disasters have in Mexican plans. However, Alexander (2015) showed how the performance of the overall Mexican disaster management system in some communities can be very poor. Moreover, problems identified in logistical activities by Santos-Reyes and Beard (2011) for a major flood in Tabasco highlighted the need to strengthen preparedness and response mechanisms in natural disasters. The explanation is elegantly summarized by Alexander (2015), stating that “the law lacks the instruments for its application”, showing that the framework for disaster management is there, but the tools required to support it are not.

3.5 Chapter summary

The advancement in research should be made always understanding the contributions of previous studies and the context at hand. This chapter introduced a literature review of relevant publications for the aim of this work, identifying the absence of articles addressing the four major activities studied here, the limited number of studies considering participation from different actors and the still understudied combination of GIS with optimisation. Afterwards, the context for this research was presented including the norms, participants and tools available for disaster management in Mexico. A gap in practice was identified which is intended to be addressed with this research.

Next chapter will introduce the ‘blueprint’ used to develop this research and tackle the problems aforementioned, detailing the rationale behind the research approach undertaken.

4 METHODOLOGY

Previous chapters have introduced the motivation behind this research (*why*), the scope of the problem tackled (*what*), and the gap in the current body of knowledge available under which this research falls (*where*). The purpose of this section is to explain the approach undertaken to accomplish the aim (*how*) stated on Chapter 1. This section elaborates on the philosophical underpinning of the project, strategy and research design.

4.1 Management research

Research is a search for the truth (Hair, 2003) and for knowledge (Kothari, 2004). The concept of research is broad and it varies from natural to social sciences, depending on the area of study. Easterby-Smith et al. (2012) introduced seven perspectives within MS according to the approach undertaken, which are shown on Table 4.1. The research proposed in this thesis is developed under the Decision Theory view, using an analytical approach aiming to optimise decisions; thereby falling under the umbrella of MS.

Table 4.1 Views of Management

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The research problem is a distinctive element of the research process because through it is possible to discover components of reality or to understand them (Thiétart, 2001). However, research depends not only on the problem but on the philosophical beliefs of the researcher. As stated by Lee and Lings (2008) "*research is about generating knowledge about what you believe the world is*". This section includes an analysis and description of the paradigm underpinning the proposed research.

4.2 Research paradigm

Figure 4.1 shows different layers of choices from the philosophical assumptions to specific techniques and procedures that should be aligned for the appropriate development of research. It is important to highlight the need for consistency across the different layers to obtain valuable results, as the approach undertaken on higher levels can affect the application and suitability of the choices on lower levels.

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Figure 4.1. Research 'onion'

At the highest level, ontology is concerned with the nature of reality and the philosophical assumptions associated to it (Easterby-Smith et al., 2012). The way the world is perceived by the researcher invariably affects the choices in terms of methods and techniques. Saunders et al. (2009) identified two main elements of ontology: objectivism and subjectivism. Objectivism takes the stand that there is a single reality and that "*social entities exist in reality external to social actors concerned with their existence*" (Saunders et al., 2009). This ontology assumes a single truth and the existence of facts that can be revealed (Easterby-Smith et al., 2012). On the other hand, subjectivism states that "*social phenomena are created from the perceptions and consequent actions of those social actors concerned with their existence*" (Saunders et al., 2009). Under this perspective, it is very difficult to determine the existence of a unique truth and facts are created by social interaction (Easterby-Smith et al., 2012), considering reality subjective depending on the observer and his/her values.

The two ontologies described above are considered of essential because these are the foundations of the two most widely known paradigms: positivism and interpretivism.

4.2.1 Positivism

Positivism assumes an objective and external reality with properties that can only significantly being measured based on observations of such reality (Easterby-Smith et al., 2012). This paradigm is associated with the scientific method (Patterson and Williams, 1998) and it has been commonly used on physical and natural sciences. Positivism relies on the idea of objective observations to test hypotheses along with the pursue of facilitating replication (Saunders et al., 2009).

Easterby-Smith et al. (2012) identified the philosophical assumptions of positivism as follow:

- Independence: the observer and the object are not affecting each other.
- Value-freedom: the choice of the subject and method is not based on human preferences or beliefs.
- Causality: causal explanations and fundamental laws are the ultimate goal.
- Hypothesis and deduction: the research process encompasses the creation of hypotheses tested to either verify or falsify them.
- Operationalization: the design should consider the objective measurement of attributes.
- Reductionism: problems can be reduced to its simplest elements for analysis.
- Generalization: representative samples should be used for the analysis to make generalisations.
- Cross-sectional analysis: comparison of variations across samples can aid the analysis.

Among the advantages of this approach are the possibility to attain high coverage studies with swift and economical processes, and very clear and transparent justification for the decision-making (Easterby-Smith et al., 2012). Nonetheless, there is an imbalance between rigour and relevance, between precision and richness, between elegance and applicability, and between discovery and verification (See Adamides et al., 2012, Guba, 1990, Lee and Lings, 2008). Moreover, research stands on the choice of topic, objective and data collection decided by the researcher, somehow involving his/her values there (Saunders et al., 2009).

4.2.2 Interpretivism

Considering reality as a socially constructed element, this movement is focused on people, individually and collectively (Easterby-Smith et al., 2012). Interpretivism states that the complex reality cannot be reduced to a series of generalisations and that the challenge is to understand the subjects and their interactions from their point of view (Saunders et al., 2009). It is important to mention that interpretivism has been used as an umbrella term associated to hermeneutics, phenomenology, social constructionism, among others (Lee and Lings, 2008).

Interpretivism can use information from multiple data sources and allow generalizations beyond the sample studied undertaking an inductive approach. Nonetheless, it relies on a level of access that can be difficult to obtain, collection of data can be expensive and timeconsuming, data analysis and interpretation can prove difficult, and as a subjective analysis the credibility of results can be arguable (Easterby-Smith et al., 2012). More importantly, under this paradigm the analysis is focused more on intangible elements that can be difficult to use to provide a decision-making system.

4.2.3 Selection of paradigm

Table 4.2 shows the implications of the two paradigms presented to allow the reader to get a better understanding of each one of them. Positivism considers a detachment of the researcher from the environment analysed focusing on quantifiable measures whereas interpretivism is more concentrated towards understanding the situation involving human interests.

Table 4.2 Contrasting implications of positivism and interpretivism

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Source: Easterby-Smith et al. (2012)

Having analysed different perspectives for this research, a positivistic paradigm was chosen based on the view of the researcher and the topic at hand. The view of the researcher is that there is a single reality to be analysed and discovered. The researcher is distant, non-interactive and independent of the phenomenon observed, taking an objective stand regarding the disaster and the overall system to be analysed.

Beyond the reasons mentioned above, the importance of using a positivistic paradigm is also the nature of the research performed. The aim of this research is to provide a support tool to aid decision-making for disaster preparedness and response by determining the most appropriate decisions based on the situation. In order to accomplish the objective, measurable and quantifiable features of the event are required to identify the solution, pointing to prescriptive models. Optimisation models are commonly considered objective and in line with the positivist paradigm (Mingers, 2003).

The dominant paradigm behind most of papers in emergency logistics is positivism (Adamides et al., 2012, Mentzer and Kahn, 1995, Patterson and Williams, 1998), with the goal to model real objects (Klein and Hirschheim, 1987) and explain and predict an objective, tangible and fragmentable reality (Mentzer and Kahn, 1995).

4.3 Research design

The research design is used to plan and organise the research activities to achieve the research aims (Easterby-Smith et al., 2012, Lee and Lings, 2008, Saunders et al., 2009). The research design is a key component stating each one of the elements necessary to accomplish the goals of any research.

After carefully planning, the design is implemented through some form of methodology/approach or research procedure (Brennan et al., 2011), including the selection of methods and techniques to employ for the research. Jankowicz (2005) defines a method as a "*systematic and orderly approach taken towards the collection and analysis of data so that information can be obtained from those data*". Broadly, Kotzab et al. (2005) highlights surveys, case studies, action research and modelling as the most common research methods used in supply chain management. For the proposed research, the two methods selected are modelling and case studies.

4.3.1 Modelling

A model is a representation of reality. The model contains the significant features or relationships of the system in order to understand it, analyse it and/or draw conclusions from it (Chang, 2002). Under the umbrella of disaster management, the context surrounding disaster situations is a major driver for decision making, and the creation of a model is suitable to consider the problem from a systems approach (Simonović, 2010). Albright and Winston (2009) identified seven steps for modelling presented in Figure 4.2, from the definition of the problem to its implementation. Given the nature and scope of the project, the first five steps are carried out as part of this research.

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Source: Albright and Winston (2009)

Figure 4.2. Seven-step modelling process

There are different classes of models, depending on the goal pursued. A very common classification is descriptive, prescriptive and predictive models (Souza, 2014). Descriptive models reflect on the current situation to explain what is happening in the system (Albright and Winston, 2009), whereas predictive modelling uses past data to identify trends and give predictions of what will happen (Souza, 2014). Prescriptive models deliver an 'optimal' policy based on the information and context (Albright and Winston, 2009). Table 4.3 shows some of the techniques associated to each one of the type of models from an OR perspective.

Table 4.3. Techniques used in supply chain management

Type of model	Tool
Descriptive	• Supply chain mapping • Supply chain visualization
Predictive	• Time series methods such as. moving average, exponential smoothing, autoregressive models • Linear, nonlinear, and logistic regression • Data-mining techniques. For instance cluster analysis and market basket analysis
Prescriptive	• Analytic Hierarchy Process • Game theory in terms of auction design and contract design • Linear and nonlinear optimisation • Network flow algorithms • Stochastic modelling • Dynamic programming • Simulation

Source: Compiled by author with information from Souza (2014)

Looking at the goals of the project, the development of a tool to support decision making on preparedness and response is associated with a prescriptive approach. The idea is to consider the conditions of the disaster situation and find the best combination of decisions to satisfy demand fairly and at the same time ensuring that resources are used adequately. This system encompasses one GIS model and two optimisation models to accomplish the objective.

4.3.1.1 Geographical Information Systems Modelling

GIS has been identified as a valuable tool for disaster management (Cova, 1999, Radke et al., 2000, van Westen, 2002) because of its flexibility and the potential to either perform analysis or to display results graphically (Jian-Kun et al., 2010). The use of spatial data to create a representation of reality can be defined as a GIS model (Chang, 2002).

Among the different types of modelling available on GIS, cartographic modelling is the simulation of a spatial decision-making process through the sequential combination of techniques and operations (Delaney, 1999). This type of modelling differentiates itself from others because of the function-oriented structure (Tomlin, 1991). In this structure each step of the operations accept one or more layers as input to create another layer as output, used on the next step to eventually reach a decision (Delaney, 1999).

Cartographic modelling uses map algebra to integrate maps of individual characteristics to treat them as variables that can be combined or transformed through specific functions (Tomlin, 1991). This type of modelling is highly appropriate to tackle analytical problems because of the potential to create countless tailor-made map-processing capabilities

(Burrough, 1986). For instance, as seen on Chapter 3, Prathumchai and Samarakoon (2005) proposed a very interesting application of this method for shelter location/evaluation by combining different layers including accessibility and altitude, among others.

Cartographic modelling allows deciding which data is required, clear and thorough analysis of the system to define the problem, inclusion of different sources and types of spatial data, a structured process, easiness for scenario comparison and the practicality of raster-based GIS for the analysis. There is a preference for raster-based models because satellite images and DEMs are relevant data sources (Chang, 2002).

The literature review has shown that the inclusion of geographical features is relevant for decision making, the kind of support GIS systems can provide to mathematical models. GIS-based models have been successfully integrated to logistic models before (Jian-Kun et al., 2010) as well as with disaster management models (e.g. Chang et al., 2007, Chanta and Sangsawang, 2012). Cartographic modelling is a technique that can be used to obtain a structured procedure able to incorporate the relevant geographical components of the region into the decision-making process.

4.3.1.2 Optimisation Modelling

Operational research has been linked to emergency response for a long time, providing a framework to perform “management of disorganisation” (Simpson and Hancock, 2009). The reviews provided by Altay and Green (2006) and Galindo and Batta (2013b) highlighted the prominent role of OR in disaster management in recent years, because of the range of techniques available, with particular emphasis on quantitative modelling (Simpson and Hancock, 2009).

Considering the value of OR for disaster management (Hoyos et al., 2015), different techniques have been applied to the problems tackled. Optimisation is the most common technique in humanitarian logistics due to the idea that supply chains can be defined by the optimisation of performance measures (Adamides et al., 2012). This quantitative approach has been chosen by several papers in the literature (e.g. Balcik and Beamon, 2008, Chang et al., 2007, Kongsomsaksakul et al., 2005) showing that many of the relevant components of the humanitarian supply chain can be embedded into an optimisation model.

Optimisation models are defined as the representation of a system used to determine the maximum/minimum of a mathematical function (Verma and Boyer, 2010, p.325, Mital, 2007, p.58). Among the main advantages of optimisation are the possibility to perform ‘what if’ analysis (Albright and Winston, 2009), identify the best combination for a set of conditions, structure the thought process, increase objectivity, and formulate complex problems on a tractable fashion (Lee-Post, 2003).

However, optimisation also has relevant shortcomings. Infeasibility and unboundedness because of problems on the model or data (Albright and Winston, 2009), system complexity or computational difficulty (Simonović, 2009), lack of consideration for behavioural processes within the environment of study (Kotzab et al., 2005), and the possibility of not modelling the real situation properly because of misrepresentation or misconception (Lee-Post, 2003).

Despite the fact that each one of the disadvantages aforementioned is considerably important, the use of optimisation modelling seems a natural fit because of the potential to consider the relevant constrains of the situation and balance all the possible combinations to find the most suitable one in terms of defined metrics. Hence, the design of two optimisation models is proposed: one for preparedness and one for response. Each model will be focused on a different stage of the decision-making process through the progression of the disaster situation, aiming to provide a suitable plan at each stage.

Focusing on the models, Section 2.4.2.2 introduced a classification of optimisation models based on linearity. Even though nonlinear models can capture more faithfully real conditions, the complexity of the solution has drawn most researchers to use linear equations on their formulations. Balancing complexity and accuracy, this research is using mixed-integer programming.

4.3.2 Case studies

There is no standard definition of a case study (Benbasat et al., 1987), but borrowing from a software engineering perspective, a case study in terms of this research is defined as *an empirical exercise based on gathering information from multiple sources to analyse one instance within a real context* (Host et al., 2012). Case studies can be able to get the picture of the conditions generated by the disaster at each case and test the performance of the system, a something very useful for the analysis of disaster management. Furthermore, Benbasat et al. (1987) pointed out the suitability of the case method where the experiences from the actors and the context are fundamental.

Stuart et al. (2002) proposed a five-stage research process from the perspective of case studies shown on Figure 4.3. The modelling diagram presented before would be embedded into the 'instrument development' stage for the cases analysed.

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Illustration removed for copyright restrictions

Source: Stuart et al. (2002)

Figure 4.3. The Five Stage Research Process Model

There has been some discussion about the nature of case studies, even being commonly acknowledged as a qualitative method (Lee and Lings, 2008). The reason is that case studies are focused on a particular area that can be used to gather data for an inductive approach. However, this method can be used in a different manner depending on the researcher, as it can be supported by different epistemologies (Easterby-Smith et al., 2012).

Disaster management has both qualitative and quantitative components. The philosophical underpinning supporting the research developed should define the perspective used.

Disaster situations are unique and uncertain events that are not controllable or replicable easily, making model testing very complicated. To further research, the features of historical disaster situations can be used to analyse deeper the environment surrounding disasters and to test different hypotheses. Based on that information, case studies can help to understand deeper the process and context, especially to provide meaningful insights on a field underexplored (Benbasat et al., 1987).

Considering the philosophical beliefs of the researcher and the objectives of this project; a quantitative approach was used aided by case studies. In that sense, catastrophic situations caused by floods can be analysed based on the number of resources deployed and the reported characteristics of the disaster. Resources such as money, vehicles, people and materials can be quantified and used to assess the situation and the behaviour of the system developed.

This research is including an objective approach in which the researcher is translating the conditions of the selected situations into numbers to incorporate into the cartographic model and the optimisation models.

To provide an adequate setting for analysis, the region selected was Mexico. Figure 4.4 shows the map of the risk of hazards of every country in the world, displaying Mexico as one of the countries with the highest hazard exposure (8.2). Also, Mexico has been classified as a country with a high Index For Risk Management (IFOR) (4.8).

In terms of the number of disasters occurred, Mexico is the most affected country by disasters in the Americas after the United States (CRED, 2016a), with an average occurrence of nearly 4 large-scale disasters per year in the last 65 years.

The impact caused by disasters is a major concern as well. Mexico has suffered nearly 4.4% of total damage caused by disasters in the Americas from 1950 to 2015, the second highest value just surpassed by the United States (CRED, 2016a).

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Source: INFORM (2016)

Figure 4.4. Hazard exposure

At the same time, Mexico counts with a dedicated authority in charge of disaster management (SINAPROC) and funds to perform disaster management. The interest is Mexico is based on the frequency of the events, the risk associated with the country and the impact caused by disasters, but also because the coping capabilities of the country. Figure 4.5 exhibits the global map of lack of coping capacity, showing that Mexico has developed capabilities to deal with disasters. Moreover, from the disasters with high hazard exposure, Mexico seems to have the lowest index for lack of coping capabilities (4.4).

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Source: INFORM (2016)

Figure 4.5. Lack of coping capacity

The combination of steep impact from disasters but disaster management capabilities makes Mexico an ideal region for the analysis, requiring support but also with resources to cope with disaster situations.

Yin (2009) stated that multiple-case analysis can be used for testing theory, a method chosen for this work. The purpose of the cases is to be able to evaluate the performance of the system under real-case circumstances, using historical data to provide the setting for the system and draw conclusions from the results. Regarding case selection, Pettigrew (1990) suggested a set of criteria as follows: the use of critical incidents, inclusion of polar types, consideration of high experience levels of the phenomena and involvement of cases with possibilities of access.

Data was gathered about disasters in the country to select the cases to focus on. Figure 4.6 shows the areas in the country that are considered to be in danger of flooding in the country according to the Mexican government (Zepeda and González, 2001). From the image a total of fifteen regions were identified as highly affected by floods.

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Illustration removed for copyright restrictions

Source: Zepeda and González (2001)

Figure 4.6. Probability of floods in different areas of Mexico

The 15 regions identified to be prone to flooding were cross-referenced with the emergency declarations in the country in recent years that required relief distribution (SINAPROC, 2013). Veracruz, Guerrero and Tabasco appeared as the most frequently affected States with 58, 27 and 15 emergency declarations requiring relief distribution from 2010 to 2015, respectively.

The three states showed high frequency of floods, and the cases were selected after searching for the worst flood experienced at each one of the States. The description of each case can be found on Table 4.4. The table includes some of the main features of the situations and the method proposed to evaluate the results from the system designed.

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Veracruz has been victim of the highest number of floods, but it is a State commonly affected by low-medium scale floods. However, the floods of 1999 (Aguirre and Macías, 2006, Vázquez Conde et al., 2001) and 2010 are evidence that major episodes also occur on the region.

In Guerrero, there are some cities affected by floods but none has been affected as much as Acapulco in 2013. The city witnessed one of the worst disasters in the country in the last 15 years. It also is commonly affected by low-scale floods.

Tabasco is also a very affected State, having Villahermosa as the most flood affected city in Mexico. Villahermosa has been commonly affected by floods of considerable economic damage in 1975, 1990 (IMTA, 2008), 1999, 2007 and 2008 (CEPAL, 2011), and in 2009 (PNUD, 2009).

Other reasons for the selection of the cases are:

- The three events are the worst floods lived in these areas over the last 15 years, providing extreme conditions for the analysis.
- The characteristics among cases vary considerably in terms of damage, duration and number of people affected.
- The three areas are relevant because of different reasons: the tourism importance of Acapulco (INEGI, 2010a), the commercial importance of Veracruz (CAAAAREM, 2009) and the high level of vulnerability in Villahermosa (PNUD, 2011).

- The different level of experience from local authorities handling disasters on the three cases due to the number of events experienced and the magnitude of them.

The difference between the three cases is mostly in terms of location, type of flood and the magnitude of the episode. Acapulco is located next to the Pacific Ocean, Veracruz is at the side of the Gulf of Mexico and Villahermosa is inland. Acapulco and Veracruz are classified as coastal floods, whereas Villahermosa was a riverine flood. Related to the scale of the disaster, Veracruz provided a small-scale disaster, Acapulco a medium-scale disaster and Villahermosa a large-scale disaster.

The value of the three cases is related to applying the system in different conditions to be able to draw conclusions. The differences on location and type of flood are valuable for testing the GIS procedure, as it is important to assess the performance of this component based on different conditions. For instance, analysing if the system can provide an accurate representation of the flood in flatland and also in a mountainous area, or if there are any limitations on estimating damage for a flood caused by the overflow of rivers compared to a flood near the coast. The difference in the magnitude of the event is particularly important for the optimisation models, to test the performance of the formulations comparing excess of resources and shortages of resources, as well as to evaluate the differences in solution time.

The analysis of the three cases presented is based on the necessity to show the potential of the system proposed. It is very difficult to generalise conclusions when a case study is involved, but by testing the system under different conditions the purpose is to suggest the appropriateness of this system for the conditions of Mexico. Also, the reliability of the model is a very important matter. Three cases are considered to be sufficient to demonstrate that the system can provide useful and coherent solutions. Finally, the cases are used to show the potential of the system designed, but also the limitations. Having different cases it is easier to spot any limitations or complications that can be further investigated, corrected or stated.

As part of the alignment of the goals of this research with the cases described, these are used to assess the research questions. The assessment methods used here are related to the research questions introduced on Section 1.4. The results of the application of the combination between the GIS and both models is presented and discussed on Chapter 5 to answer RQ1. Afterwards, scenarios with and without GIS for the three cases will be tested to contrast results and evaluate the impact of introducing the GIS and answer RQ2. In terms of the importance of the inclusion of multiple organisations, RQ3 will be assessed by comparing scenarios with independent decision-making and the coordinated approach encouraged by this research. Finally, the results of both models will be contrasted with the *best possible* scenario of real activities performed by authorities on the three cases to draw conclusions and answer RQ4.

4.4 Data collection

The case studies are developed using historical data from the organisations involved in the management of each one of the disaster situations. Optimisation models require large amounts of quantitative data, which can be obtained from secondary sources. Similarly, cartographic models are based on the use of different layers integrated into a sequential procedure (Tomlin, 1991) that can be obtained from secondary sources.

Data collection performed in this project is based on the combination of publicly data available online and information requests to different governmental and non-governmental organisations.

Departing from the GIS procedure, the basis for the analysis are digital elevation models (See Burrough, 1986) which are publicly available from the website of the United States Geological Survey (USGS) *(*www.usgs.gov*)* and the website of the National Institute of Geography and Statistics (INEGI) in Mexico (http://www.inegi.org.mx/). Layers about the road network and neighbourhoods denominated Basic Geo-Statistical Area (AGEBs) were obtained from publicly available software developed by INEGI named SCINCE 2010.

For the optimisation models, demographical data can be obtained from SCINCE 2010, geographical data can be calculated using vector and raster GIS, and the wages for relief personnel are available on the transparency website of the Mexican Government (http://portaltransparencia.gob.mx/buscador/search/search.do?method=begin). The rest of the information is requested directly to each one of the agencies involved. Official information requests (FOI) to Federal and local agencies about archive material can be performed for each one of the cases. The purpose is to obtain data about facility management, human resources used and activities performed, vehicles placed, relief items distributed and operative costs. Each request contains a brief statement of the purposes of the research, the intended use for the information and the people responsible for it.

To complement information requests, talks with representatives of CENAPRECE and the Office for the Coordination of Humanitarian Affairs (OCHA) are used to understand disaster response from the perspective of governmental and non-governmental organisations. For these meetings, besides the above statement for information requests, the researcher provided an oral overview of the research project, declare the duration of the meeting and make sure the contacts understand the scope of the research.

The information collected online is labelled with time, date and source, encrypted and stored on a computer on the research group, whilst the information collected by request will be stored on a personal secured cabinet at the research group and electronically backed up.

4.5 Data analysis

The information from the requests was obtained in the form of tables or pieces of information on PDF or Excel formats. The information on PDF was transferred to Microsoft Excel® and combined with the remaining data to create databases.

For the geographical component of the research two software packages were selected. For data pre-processing and network analysis, TransCAD® was chosen (http://www.caliper.com/tcovu.htm), whereas the cartographic model was incorporated on IDRISI® (http://www.clarklabs.org/). The procedure developed by Martin (1993) and extended by Rodríguez-Espíndola and Gaytán (2015) is intended to be used to create a macro on raster GIS.

TransCAD® is a powerful vector GIS used for transportation applications (Mi et al., 2012, Peter van der and Harry, 2010, Yu and Yan, 2010, Voigt et al., 2009), but it also has proven useful for emergency applications (Andrews et al., 2010, Andrews, 2009). TransCAD® has been coupled with optimisation models for disaster management for network analysis (Horner and Downs, 2010, Horner and Downs, 2007, Tzeng et al., 2007)*. Despite the value of software such as ArcGIS®, the transportation capabilities of TransCAD® were desirable for network analysis and layer management. On the other hand, IDRISI was chosen because of the need of raster-based GIS for cartographic analysis* (Chang, 2002) and the suitability showed for flood applications (Kandilioti and Makropoulos, 2012, Muzik, 1996). Also, there is previous work on floods developed in Mexico utilizing this software (See http://idrisi.uaemex.mx).

Combining the results from the geographical analysis with the rest of the databases, the input for the models was obtained. Both models were programmed on the General Algebraic Modelling System® (GAMS®) to apply a multi-criteria decision making method for solution. Ramos et al. (2010) provided a clear comparison between programming models on common languages, numeric analysis language and algebraic languages. Examples of common languages are C++, Java and Visual Basic; whereas MATLAB®, MAPLE® and Mathematica® use numeric analysis languages. Software supporting algebraic languages, such as GAMS®, AMPL®, XPRESS-MP®, are the most powerful alternatives combining flexibility for changes on the model, simpler maintenance and easier detection of errors (Ramos et al., 2010). The most popular and common software using algebraic language is GAMS® and it has been used by a wide variety of papers on disaster management across different activities (e.g. Mete and Zabinsky, 2010, Duran et al., 2011, Salmeron and Apte, 2010, Galindo and Batta, 2013a, Tirado et al., 2014). GAMS® was selected along with Cplex® as a solver, a very common combination in the literature.

4.6 Verification and validation

The design of every model has to include a section about the evaluation of the adequacy of the model; that is the process to check that the model delivered is actually working properly. Usually this is related to the concepts of verification and validation (Sargent, 2013), which are important for the selection of a model (Ronchi et al., 2014). Even though these concepts are commonly related to simulation models, any model-based approach has to consider the reliability of the model (Ziwei and Zhimin, 2014).

The difference between both concepts is that verification is ensuring the theoretical idea of the model was successfully implemented into the computer model, whereas validation is more related to building the right model for the problem at hand (Robinson, 1997). For this research, verification and validation were performed on each one of the models provided.

Suggestions from Sargent (2013) and Ronchi et al. (2014) were used to make sure the model behaved as expected, whereas validation was performed through face validity shown on Table 4.5 and based on the results of Chapter 7.

Table 4.5. Validation of the models

Event	Cartographic model		Preparedness model		Response model	
	Academic review	Practitioner review	Academic review	Practitioner review	Academic review	Practitioner review
Conacyt Symposium 2013	✓					
MORS PhD showcase	✓					
Midlands colloquium 2014	✓		✓			
HUMLOG 2014 conference	✓	✓	✓	✓		
IFORS 2014 conference	✓	✓	✓	✓		
OR56 conference	✓		✓		✓	
MORS invited presentation 2015	✓		✓			
ISCRAM 2015 conference	✓	✓	✓	✓		
EURO 2015 conference					✓	
YoungOR 19 conference	✓		✓		✓	✓

4.7 Ethical considerations

There were no live subjects of study and the information is gathered from secondary sources.

4.8 Chapter Summary

The research proposed is quantitative in nature, an approach commonly adopted in emergency logistics. Considering the philosophical paradigm underpinning the proposed research and the objectives proposed, modelling was selected as the corner stone of the research, coupled with case studies to analyse different historical disaster situations presented in Mexico. The use of optimisation models is aiming to find the 'optimal' solution to aid decision-making in case of disaster, whereas cartographic modelling seeks to include the spatial dimension of the situation. The research design is outlined on Table 4.6.

Table 4.6. Summary of the proposed methodology

<table>
<tr><td>Philosophical paradigm</td><td>Positivist</td><td rowspan="2">Techniques</td><td rowspan="2">Optimisation modelling
Cartographic modelling</td></tr>
<tr><td>Research approach</td><td>Deductive</td></tr>
<tr><td>Research methods</td><td>Modelling
Case studies</td><td rowspan="2">Tools</td><td rowspan="2">GAMS®
IDRISI®
TransCAD®</td></tr>
<tr><td>Data type</td><td>Quantitative</td></tr>
<tr><td>Data gathering</td><td>Secondary data</td><td></td><td></td></tr>
</table>

Having defined the ‘blueprint’ for the research, the next chapter is dedicated to the explanation about the development of each one of the components of the system proposed.

5 SYSTEM DESIGN

Having a well-defined process, the development of the models was undertaken. This chapter elaborates on the design of each one of the components of the system proposed, including a cartographic model and two optimisation models. The cartographic model is intending to incorporate the geographical nature of the area under study whereas the optimisation models are utilized to perform the analysis and propose suitable solutions for the decision-maker. This chapter introduces the main elements of each one of the models, along with relevant information for the application of the system and expected results.

5.1 Geographical procedure

The incorporation of the geographical features of the region has been considered relevant for location decisions in disaster management (Saadatseresht et al., 2009, Zhao and Chen, 2015, Esmaeili and Barzinpour, 2014, Salman and Yücel, 2015). Identifying safe facilities is essential to run smooth operations, prevent demand excess caused by closed of facilities, and avoid the need to transfer people. According to the Mexican framework, this evaluation should be performed by local authorities and should be aided by risk atlases. A risk atlas is defined as a *set of maps showing information graphically about dangers and/or threats for a specific region* (SEGOB, 2006c), and the first one published in Mexico was developed in 1994. Nowadays the National atlas is still heavily incomplete and local atlases are even on poorer conditions (Alexander, 2015). That is the reason Saldana-Zorrilla (2015) highlighted the paramount importance of developing detailed risk atlases for adequate disaster management in the country. Recently, CONAGUA (2011) enumerated the reasons for the failure in the development of the atlases, including the lack of archive material, financial resources and human personnel. Consequently, disaster planning is not based on the analysis of hazard scenarios nor geographical factors. (Alexander, 2015)

CONAGUA (2011) summarised some of the available information for the development of a flood control plan. Among these are digital elevation models (DEMs), climatological and meteorological information, hydrological data, infrastructure, territorial division and geological databases. Departing from that, the aim was to incorporate a procedure in the analysis that could use some of that information to support the optimisation models.

The geographical procedure proposed is illustrated on Figure 5.1. It incorporates a combination of vector and raster geographical information systems. The vector GIS is used for data pre-processing and post-analysis, whereas the cartographic model is integrated on the raster GIS. This part introduces the steps presented in the figure.

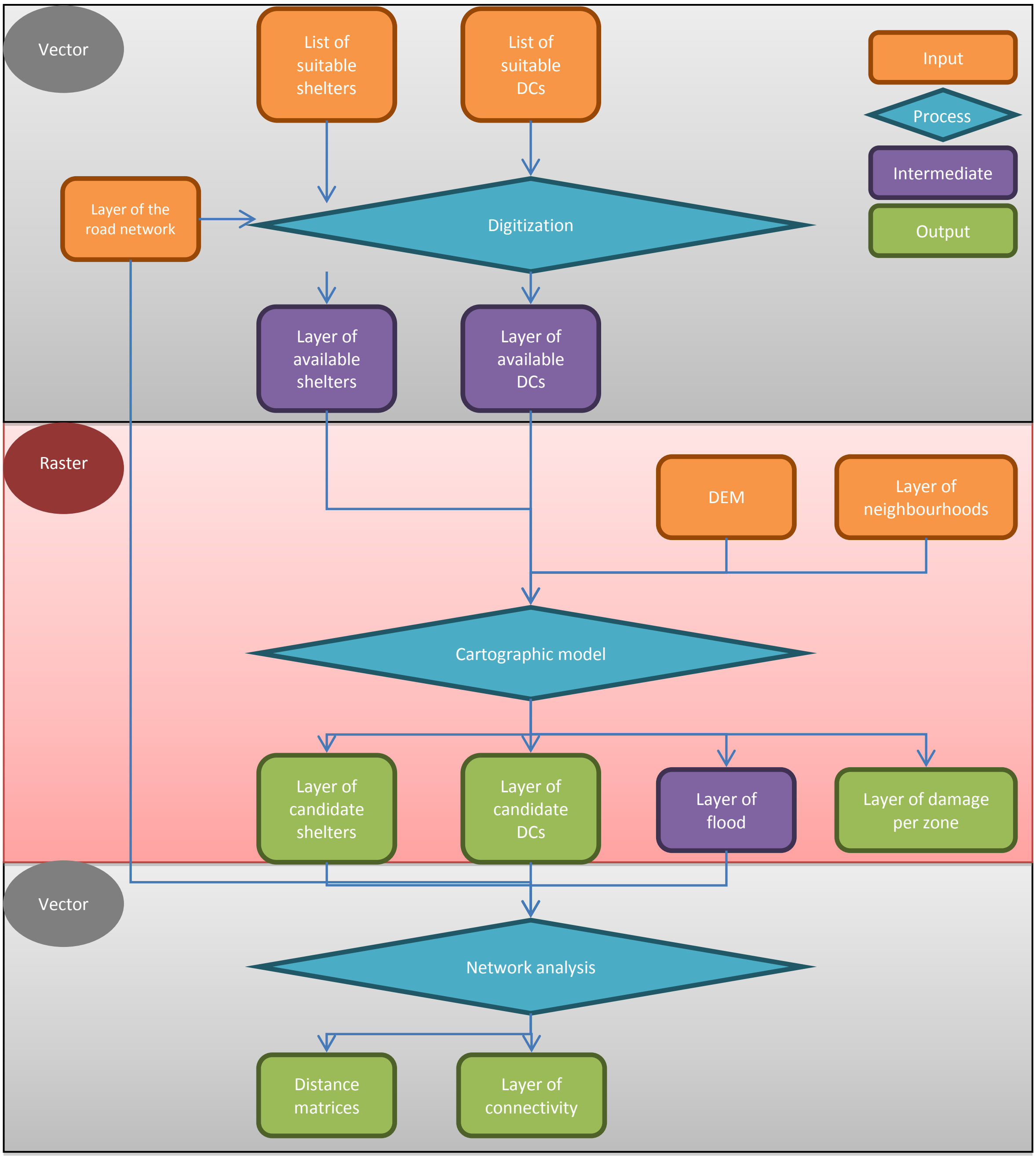


Figure 5.1. Geographical procedure

5.1.1 Identification of suitable facilities

Emergency facilities play a vital role on the development of logistical operations for disaster management. This is the reason why, prior to the application of any procedure, it is important to perform due diligence to determine appropriate facilities to serve as shelters and DCs. As seen on Section 3.3.1, facility location can be associated with the construction of facilities, the selection of buildings among a list of available places and the use of transportable temporal shelters. According to SEDENA (2010), in Mexico the usual procedure is to select facilities considering existent buildings. Transportable shelters are used for operations abroad, whereas the construction of buildings exclusively to serve as shelters can be prohibitive in terms of cost.

In that sense, including only facilities that fulfil certain standards affects directly the level of service provided to disaster victims. For instance, the inclusion of police booths to shelter four people in Villahermosa (SEGOB, 2014b), one of the most flood-affected cities in Mexico, seems inadequate. This section introduces the requirements for emergency facilities.

5.1.1.1 Shelter standards

Even though there was a project to regulate the operation of shelters (PROY-NOM-005-SEGOB-2012) there is no official regulation about shelter requirements in Mexico. Table 5.1 shows the minimum living requirements identified by the Sphere Project and the National Centre For Disaster Prevention (CENAPRED) in Mexico, from an international and national perspective, respectively.

Table 5.1 Living requirements for shelters

	Requirement	**CENAPRED**	**Sphere Project**
Conditions	Total space available per person	-	45 m^2
	Minimum volume of air per person	10.0 m^3	
	Minimum distance between beds	0.75 m	
	Minimum covered floor area	3.5 m^2	3.5 m^2
Personal hygiene	Washbasin	One per 10 people	
	Shower	One per 50 people in warm weather, one per 30 people in hot weather	
	Hygiene facilities	Separate sections for male and female	
Toilets	Female	One per 25 woman	
	Male	One toilet and one urinal per 35 males	
	Minimum distance between buildings	50 m	

Source: Compiled by author with information from Sphere_Project (2011) and CENAPRED (2009)

Also, a summary of relevant criteria for the selection of shelters was suggested by CENAPRED (2009) and SGGSLP (2015). A shelter should:

- Be located away from risky areas
- Have a low level of vulnerability
- Possess space and electrical power to provide basic services
- Be accessible
- Have access to potable water and sanitary services
- Possess a slight slope to enhance natural drainage
- Have alternative uses for non-emergency circumstances

Several criteria beyond cost, time or distance have been used in the literature to find suitable facilities. Accessibility, capacity, adaptability, zone danger and a large number of roads close by are amongst the most relevant (e.g. Kongsomsaksakul et al., 2005, Prathumchai and Samarakoon, 2005, Alam, 2000, XU et al., 2007). Therefore, the selection of facilities should consider this kind of physical factors beyond common metrics to ensure adequate service for disaster victims.

5.1.1.2 Standards for distribution centres

There is no official regulation for DCs in cases of disaster. However, rule NOM-120-SSA1-1994 contains the requirements for storage facilities in general. The most relevant requirements are included on Table 5.2.

Table 5.2. Minimum requirements for storage facilities in Mexico

Section	Requirement
Courtyard	• Avoid the accumulation of unused equipment, garbage, herbs. • Have adequate drainage and lighting.
Building	• Adequate condition of the buildings to avoid contamination of the products.
Floors	• Should be waterproof, with slope towards the drainage, and adequate to ease disinfection and cleaning.
Walls	• Washable and waterproof painting.
Sailings	• Avoid accumulation of dirt and condensation to prevent mould and germs.
Windows	• With protections to avoid the entrance of dust, rain and animals.
Doors	• With protections to avoid the entrance of dust, rain and animals.
Hygiene	• Should have toilets and washbasins in the bathrooms, and washbasins for cooking areas.
Ventilation	• Adequate means for ventilation should be ensured.

Source: NOM-120-SSA1-1994 (1994)

On top of that, Shradhanjali (2011), SNHD (2011) and USAID (2011) considered important for these facilities not to be located on risky areas and evaluate possible dangers for natural disruptions.

The requirements are used to draw up a list of suitable facilities used as input in the process displayed on Figure 5.1, in order to create a layer to include as part of the cartographic model.

5.1.2 Digitization

The next step is to turn the list of facilities into layers in the GIS with georeferenced information. The process of turning data into a layer is called digitization and it can be performed either on raster or vector software. Vector software was chosen because the metadata of the road network includes information about each street, allowing the user to locate each facility easily and efficiently. Moreover, if the list includes coordinates these can be swiftly incorporated.

The digitization process can be performed by importing the layer of the road network into the software and then creating a new point layer overlapping with the road network. In TransCAD®, using *Tools/Map Editing/Toolbox* each point can be digitized into the layer. This way, a layer for shelters and another one for distribution centres can be created.

5.1.3 Cartographic model

To perform the analysis of different scenarios, a cartographic model was implemented into a macro in IDRISI®. The parameter used to vary scenarios relies on the *expected* water height, because of weather conditions or a particular phenomenon. The goal is to create a flood map. Flood maps are aligned with the results expected by Mexican authorities with risk atlases, and these have shown advancements in the literature (e.g. Simav et al., 2013, Patel and Srivastava, 2013, Isma'il and Opeluwa Saanyol, 2013, Bhatt et al., 2013, Ajin et al., 2013). This approach was preferred because of the deterministic nature of the model, considering the potential to create a set of relevant scenarios based on weather predictions, hydrological analysis or historical data (See Theiling and Burant, 2013, Qi et al., 2013, Rawat et al., 2012, Paiva et al., 2011, Waisurasingha et al., 2008, Dutta et al., 2007, Overton, 2005, Chang et al., 2000). The cartographic model was obtained from the work of Martin (1993) complemented with map algebra proposed by Rodríguez-Espíndola and Gaytán (2015); all integrated into a macro in IDRISI®*. The reason for the selection of this particular model over other methods found in the literature was the scope of this work not seeking to perform hydrological and/or hydrodynamic analysis of water bodies, but just considering the expected impact of the flood, easiness and accuracy of results obtained by* Rodríguez-Espíndola and Gaytán (2015). Besides, this method has been successfully coupled with an optimisation model before.

5.1.3.1 Data pre-processing

As shown on Figure 5.1, to use the macro developed four layers are required:

- The layer of available DCs, obtained from authorities or created using the steps from Section 5.1.2.
- The layer of available shelters, obtained from authorities or created using the steps from Section 5.1.2.
- The DEM of the area under study, obtained from online sources or from authorities.
- The demand unit of the region, determined by the user and obtained from authorities.

Commonly, layers including the road network and demand units are available in *shape* format, which can be imported by raster software using the *ShapeIdr* module. Similarly, the DEM can be imported using the *BILIDRIS* module. In case the images are projected on a different reference system, the user can apply the module *project* to change the reference system of any layer.

To use map algebra, every image should be on a raster format. The user must employ the *RasterVector* module to the necessary layers to bring all of them under the same format.

Otherwise the process will stop because map algebra relies on the assumption that every layer contains the same spatial information.

The last step before using the macro is to determine the reference level. This step has to be performed only once for the region, being used for all experiments and it is associated to the altitude of the area under study. For the macro to be used, the region should be brought to a “base situation” by extracting the altitude of the area. Because of the accuracy of images and uncertainty on the real altitude, the user can perform scenario analysis with the DEM. The value of the altitude can be determined as the point where the area is affected by rising one extra unit. Also, if a water body is nearby, the reference would be the point when the water body leaves its natural course, i.e. overflow.

5.1.3.2 Macro on IDRISI

Having all the layers and information ready, the user can apply the macro displayed on Figure 5.2.

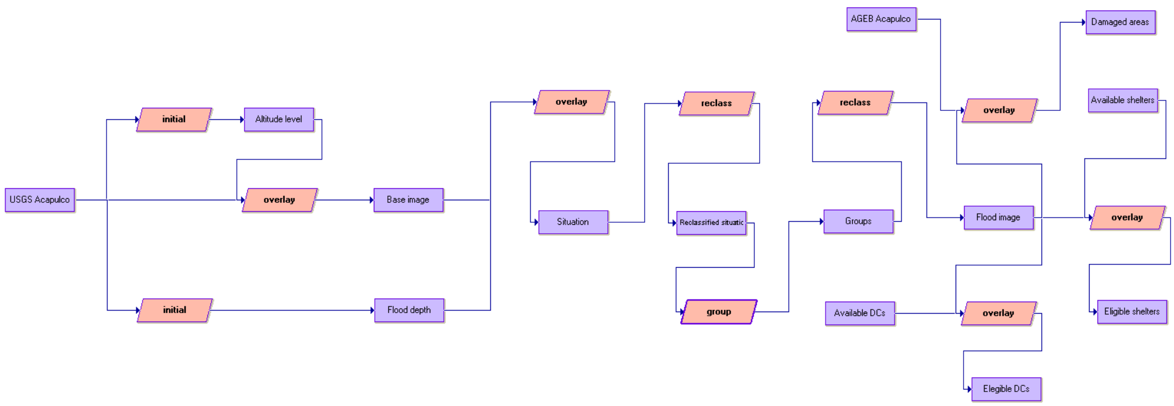


Figure 5.2. Cartographic model

The macro was created using the *Macro Modeler* module on IDRISI®*. As can be seen in the figure, the analysis orbits around the DEM in order to create the flood map. The squares in red are modules, whereas the squares on purple are maps. The top initial module on the left hand side is used to incorporate the altitude level of the area, and it is subtracted from the DEM with the first overlay to create the “Base image”. Then, the expected height of the flood is included on the bottom initial module and subtracted using an overlay to create the “Situation” layer. A reclass module is used to classify every positive value with 1 and non-positive values with 0. Afterwards,* Martin (1993) *suggests the use of the group module to join adjacent flooded pixels separated by small areas which probably are flooded as well. Afterwards, the reclass module is employed again to obtain the “Flood Image”. Building upon that,* Rodríguez-Espíndola and Gaytán (2015) suggested that map algebra could be used to evaluate the damage caused by the flood and discard floodable facilities. On the top of the right hand side, an *overlay* module is used to ‘multiply’ the demand areas times the flood image, getting as a result a value of 0 on every zone under water and the ID of the demand unit for the rest. The *area* module can be employed to obtain the percentage of the initial area of the demand unit and the dry area after the flood. Similarly, the layers of facilities are multiplied times the flood image, and the module *area* is used to obtain a list of facilities on dry sections only. This procedure can be applied as many times as desired by the decision maker including scenario analysis for relevant situations.

Finally, using the suggestions from Sargent (2013) for verification, the cartographic model had to checked to obtain an error-free macro for the analysis. Each one of the modules were revised and the procedure was applied under different parameters to ensure appropriate working. Also a walk-trough was performed step-by-step, to make sure each stage is accomplishing the expected outcome by checking the parameters input and the result. For this part, each one of the modules was evaluated individually considering the layers input and the obtained output. Finally, the reprogramming of critical components and relationships along with the modification of parameters was performed. The idea was to change the modules and parameters in different sections to make sure the results were replicable and the effect of each one of the sections. For instance, the modules involved with the 'Base situation' were substituted. Then the modules related to the flood map were changed, and at the end the modules related to the output of the model were varied and revised.

5.1.3.3 Network analysis

After the flood image is obtained, it can be superposed with the road network to identify roads affected. This research is assuming a single collection point per demand unit for the departure from affected areas to shelters, termed *centroid*. Having all the candidate facilities and demand points, the user can check the existence a road available between two points. Considering the number of combinations can be monumental, the Floyd-Warshall algorithm is proposed as a time-saving option.

The Floyd-Warshall algorithm (Warshall, 1962, Floyd, 1962) is one of the most widely used and effective algorithms to determine the shortest path between two points (Aini and Salehipour, 2012, Höfner and Möller, 2012). The algorithm is capable of finding the minimum distance between all pairs of nodes in a graph, even considering negative weights, unlike Dijkstra's algorithm (Kleiman, 2001). Considering a square matrix D_{ij} with partial values, the algorithm is displayed on Figure 5.3.

```
For k = 1 to n
{
        For i = 1 to n
        {
                For j = 1 to n
                {
```

```
s=D_ik + D_kj
If (s < D_ij)
{
D_ij = s
}
}
}
}
```

Source: Compiled by author with information from Warshall (1962) and Floyd (1962)

Figure 5.3 Floyd-Warshall algorithm

The algorithm presented compares the 'current' direct distance with the distance obtained by visiting node *k* in between nodes *i* and *j*, and collecting the lowest value for the matrix. One matrix is computed for each node checking connectivity *k* number of times. This algorithm is capable of finding a suitable route even if the value was not included in the initial matrix, by verifying every path available.

For the problem at hand, the idea is to create a matrix with initial values of connectivity using 1 for the existence of a path and a very large for the rest. Then, the algorithm can be implemented on a numerical analysis language (See Section 4.5) to get the solution. From the results, every value different to the large number included initially is considered as an existent path and non-connected otherwise, representing 1 and 0 respectively. For the purposes of this work, the algorithm was implemented in MATLAB®*. The result is the connectivity matrix used by the optimisation model, affecting road and boat transportation.*

It is also important to determine the shortest distance between every pair of nodes. A common practice is to compute Euclidian distances for the analysis. Nevertheless, having GIS available, another level of detail can be attained. Initially, the layers of facilities and demand areas have to be merged into one. This can be easily done importing the three layers into ArcGIS® and using the *Geoprocessing* extension to employ the *merge* module. Then, the user can decide whether to use the *Network Analyst* on ArcGIS® or export the resulting layer as a *shapefile* and import it into TransCAD®. Using the latter, a new field in the structure of the layer should be created to use the *tools/map editing/connect* option to link each facility to the road network, with the new field being filled by the ID of the facility/area. Next, the nodes with ID are selected and the *Network paths/multiple paths* tool is used to obtain a matrix of the shortest road path. Also, using *tools/geographic analysis/distance matrix,* a Euclidian distance matrix can be obtained for air and boat transportation.

The results from the geographical procedure is a list of candidate facilities, a matrix of connectivity between facilities along with the distance between them, and a percentage of damage caused by the flood to the demand areas.

5.2 Preparedness optimisation model

The purpose of the model is to determine the location of shelters and DCs, establish the allocation of material and human resources to use on each activity, decide which agencies should be involved according to the event, and perform the allocation of distribution for the initial response phase right after disaster. This section introduces the assumptions considered for the development of the model, the information required for application, the rationale behind the design of the model, the notation used, the formulation of the model and the solution methods applied.

5.2.1 Model assumptions

Even though there are several advantages of optimisation models, in general models can only approximate reality (Delaney, 1999). Therefore, a clear set of assumptions underpinning the model ought to be established in order to limit its scope and have a manageable set of variables. The main assumptions of the preparedness model designed here are as follows:

- There is one overarching decision-maker authority in charge of creating the preparedness plan and coordinating the other organisations.
- The variables included in the model are deterministic.
- The agencies involved in planning are available for immediate deployment.
- Once an agency is activated, relief owned by that agency can be delivered by any agency.
- The activation of an agency yields the payment in full of the payroll of every member of the organisation.
- Transportation costs are only dependent on the fuel spent to perform the delivery. Vehicles are pre-owned by the organisations involved, leaving depreciation aside.
- Evacuation is assumed to be performed with total availability of the road network, considering traffic assignment outside the scope of this work.
- People are informed before the evacuation about the shelter allocated to each one of them.
- There is no quantifiable holding cost.
- Routing can be performed using one of the algorithms found in the literature (See Golden et al., 2008, Toth and Vigo, 2007) or the expertise from local drivers (de la Torre et al., 2012).
- The number of facilities to set-up is based on the resources available along with the features of the disaster, not a pre-defined number determined by authorities.
- Both objectives are relevant for the decision maker and there is no clear dominance from one to the other.

All of the above assumptions were discussed at the initial stage of development and considered in line with the goals of the project.

5.2.2 Data requirements

The application of the model requires a large amount of data to be determined beforehand. The creation of databases is advised including:

- The list of available facilities along with their capacity (people for shelters and storage for distribution centres), location and opening cost.
- The list of demand areas along with the number of people to serve and their location.
- The list of transportation modes including type, capacity, fuel consumption and required number of people per vehicle.
- The list of commodities including their size, weight, level of priority, cost and number of people served per unit.
- The list of agencies including the number of people available per activity, the number and type of vehicles available, the number of type of relief available, and the wages associated with each one of them.
- Personnel requirements for the management of DCs, shelters, healthcare and distribution.
- Trips per day per mode determined based on working hours, docking time and loading-unloading time.
- Shipment cost, connectivity and coverage availability from each distribution centre to each shelter.
- Threshold for shelter coverage with respect to the demand areas.

The GIS can provide the lists of facilities, road connectivity, and distances to estimate shipment costs based on fuel consumption. Also, it can aid demand estimation considering the expected damage caused by the disaster. The rest of the information can be obtained from individual agencies about their resource availability. Among the thresholds determined by the decision maker, the number of trips per day, personnel requirements and facility coverage can be established using expert judgement.

5.2.3 Model justification

The model designed contains only deterministic variables. Liberatore et al. (2013) identified five sources of uncertainty on emergency logistics: demand, demand location, affected areas, supply and transportation network. As seen in the literature review, there are different authors addressing each one of them individually or in conjunction. For the case of this research, demand estimation is outside of the scope considered and it is expected to be determined with forecasting methods (See Sheu, 2007b, Sheu, 2014), applying GIS for mapping and assessment (e.g. Tehrany et al., 2013, Bajabaa et al., 2013, Khan and Khan, 2013, Usha et al., 2012, Sarhadi et al., 2012, Dawod et al., 2012, Kia et al., 2012, Wang et al., 2011, Punithavathi and Tamilenthi, 2011, Kourgialas and Karatzas, 2011, Hoque et al., 2011), and/or using surveys of past events (See Shaw et al., 2011 pp. 79). Uncertainty in supply is neglected because of the preparedness nature of the model and the pre-positioning strategy adopted, not to mention the 'limitless' availability according to Mexican authorities (SEDENA, 2010). The transportation network is evaluated using GIS, and scenario analysis can also be employed to use only safe roads even under the hardest conditions. Overall, the use of a deterministic approach is related to the scope of the research, the advantages of GIS and to avoid overcomplicating the model.

The model can be classified as static, because it is considering only one period. The reason is the fact that the model is focused only on the preparedness stage and initial response, thus considering only the first period of disaster. This is aligned with the common trend of articles for facility location, stock prepositioning and relief distribution developed in the literature (e.g. Murali et al., 2012, Lejeune, 2013, Bozorgi-Amiri et al., 2012, Klibi et al., 2013, Noyan, 2012, Hong et al., 2015, Esmaeil and Barzinpour, 2013, Barzinpour and Esmaeili, 2014). This research proposes a preparedness model to provide the initial response and a response model to be applied for the rest of the event.

As pointed out by Beamon (1999) and Beamon and Balcik (2008), the use of one performance measure can be inadequate for disaster management, even with the development of 'social cost' functions (See Yushimito et al., 2012, Holguín-Veras et al., 2013, Jomon Aliyas and Hariharan, 2012, Sheu, 2014, Huang et al., 2015). We acknowledge the substantial contribution from these performance measures and it is worth stating that the authors are taking a step forward for the development of victim-oriented functions. Nonetheless, it is really difficult to address planning and preparedness using a multi-period approach as presented by most of the articles using 'social cost' functions. Only Jomon Aliyas and Hariharan (2012) considered a static model for location-allocation in line with the purposes of preparedness, but the authors are incorporating the cost of fatalities, which can be arguable from the ethical point of view. As a matter of fact, at the core, all these functions are seeking to integrate cost and suffering under the same model, which is a simplified approach of a multi-objective formulation. It is our belief that a multi-objective approach can provide higher flexibility by providing the decision-maker with a set of efficient points among which to choose the solution based on his/her preferences. Hence, in this model two objective functions related to efficiency (i.e. cost) and effectiveness (i.e. fill rate) are employed.

The selection of cost as performance measure is link to the value of considering resource-based measures (Beamon and Balcik, 2008). Cost is the most common performance used in the literature, as shown on Chapter 3, and this factor is very relevant for Mexican authorities (Rodríguez-Espíndola and Gaytán, 2015, Rodríguez-Espíndola, 2011). Holding cost was initially considered, but authorities in charge of relief items declared not to consider a real holding cost because the resources are available for other activities and the kits are prepared immediately before sending (DICONSA, 2014b). The inclusion of the activation of agencies introduces a term in the cost function related to personnel wages. Considering that people have to be pulled from their normal activities, the wages are incorporated in the model. Once an agency is activated, the resources of the agency are completely put at the disposal of disaster management. The reason is linked to the linearity of the model.

The second performance measure is related to fill rate, measure used as a proxy of the level of service provided to disaster victims on the shelter. In the same way that the cost function is considering the perspective of authorities, the second performance measure is adopting the viewpoint of the victims. Looking at distribution, there are several articles considering demand satisfaction (e.g. Liberatore et al., 2014, Tricoire et al., 2012, Abounacer et al., 2014, Chang et al., 2014, Tirado et al., 2014, Ahmadi et al., 2015, Huang et al., 2015), suggesting a mind-set focused on the victims. The point here is to extend that idea into an overarching objective for the whole system, meaning that not only distribution but location decisions are also linked to the service provided to people. The fulfilment rate is measured in three dimensions: the fulfilment of relief items, the presence of healthcare personnel for injuries and diseases, and the availability of shelter personnel to deal with security, cooking, leisure, among others. These three elements are identified as the assistance provided by Mexican authorities in shelters (SEDENA, 2010, SSPPC, 2014d, SEDENA, 2014g, SEDENA, 2014q). The purpose of this function is to contribute to the change of paradigm from common performance measures to victim-oriented measures. Even though the function is not directly measuring suffering, it is in fact measuring the level of service provided to victims in terms of products and services inside the shelter, which in turn alleviates the suffering experienced by people.

According to Savas (1978), there are three key performance indicators for public services: efficiency, effectiveness and equity. So far this work has introduced the first two measures used on this research as part of the objective functions. Even when fairness and equity have been used interchangeably in the literature (McCoy and Lee, 2014, Ogryczak, 2009, Savas, 1978), there are articles considering the priority on the demand area as a measure of fairness to inform relief distribution (Renkli and Duran, 2015, Salman and Yücel, 2015, Rennemo et al., 2014). There is a conflict between equity and priority because the former is seeking to provide services impartially among all of the actors involved, whereas the second is giving preference according to the level of disturbance to the area. Both approaches are worthwhile, but the decision about which one to apply should be based on the system. For this research, services are only provided on shelters, which are assumed to be located on safe areas. As shelters are equally safe there are no priority areas, thereby understanding equity as the balanced level of service across all shelters.

The formulation is using a min – max objective function, which can be classified as an equality-based method (Huang et al., 2015) similar to the perspective applied by Barzinpour et al. (2014), Liu and Guo (2014) and Tzeng et al. (2007). The purpose is to minimise the maximum level of unfulfillment among all shelters, seeking to balance the level of service in the entire system across shelters.

The value of most of the constraints can be justified by the use of similar restrictions in the literature regarding capacity (e.g. Kulshrestha et al., 2011, Ng et al., 2010, Sherali et al., 1991, Coutinho-Rodrigues et al., 2012, Li et al., 2011, Mirzapour et al., 2013, Rath and Gutjahr, 2011, Horner and Downs, 2010, Gormez et al., 2011, Widener and Horner, 2011), vehicles (e.g. Wisetjindawat et al., 2014, Song et al., 2009, An et al., 2013, Han et al., 2011, Özdamar et al., 2004), transportation (e.g. Davis et al., 2013, Liberatore et al., 2014, Huang et al., 2015, Rodríguez-Espíndola and Gaytán, 2015), prepositioning (e.g. Verma and Gaukler, 2014, Renkli and Duran, 2015, Galindo and Batta, 2013a, Jomon Aliyas and Hariharan, 2012, Rodríguez-Espíndola and Gaytán, 2015, Mete and Zabinsky, 2010) and personnel (e.g. Barbarosoglu et al., 2002, Abounacer et al., 2014, Sheu, 2014, Wisetjindawat et al., 2014, Brown and Vassiliou, 1993a, Falasca and Zobel, 2012). Additionally, the partial operation of DCs is considered for cases where authorities have limited resources, or the situation does not require the full opening of these facilities.

This formulation is incorporating an original component related to the activation/deactivation of organisations. In that sense, Section 2.3.3 highlighted the value of considering the balance between shortages and oversupply of resources, i.e. use only the resources needed. Even though there are reports in the literature about shortages and convergence, that aspect is still heavily understudied. This research is addressing that limitation by including a binary variable to control the number of organisations involved. By including the activation and deactivation of agencies resources can be used more efficiently, thereby preventing useless deployment of resources. This way, only organisations with resources relevant to the situation are involved. The assumptions presented are introducing the need of one overarching decision-maker. Having centralised coordination allows the model to integrate organisations regardless of their affiliation, meaning that non-governmental organisations can be incorporated and considered equally as any governmental organisation.

5.2.4 Design rationale

The proposed preparedness model is tackling issues related to facility location, stock prepositioning, relief allocation and immediate relief distribution. Table 5.3 summarises the main decisions undertaken by the model.

Table 5.3. Set of decisions determined by the preparedness optimisation model

Decision	Decision
Location of shelters	Allocation of vehicles
Location of distribution centres	Service allocation for distribution
Personnel used for each activity	Allocation of personnel
Vehicles used	Number of trips required
Demand per shelter	Relocation of people
Agencies involved	Shipment quantities
Stock prepositioned	Mode selection

The model aims to minimise both total cost and service unfulfillment percentage. The first is determined in terms of facility set-up cost, procurement cost, cost of activating an agency and transportation cost, whereas the latter is composed by healthcare, shelter care and the provision of relief items. Evidently both measures are in conflict, and the purpose is to find the set of efficient solutions to present to the decision-maker in order to decide the most-preferred policy. The decision is based on the trade-off of objectives. For instance, activating agencies increases cost but improves service on shelters, whereas money can be saved by not activating organisations but the service provided would be poor.

Elaborating on fill rate, the unit used is percentage of people satisfied per shelter. Based on expert knowledge from authorities, the number of people covered per shelter and health personnel is determined. Similarly, every relief item is prepared to serve a certain number of people for an amount of time. The combination of the three components is transformed into an index considering the capacity of the shelter, as shown in the objective function. That function is minimising the maximum level of unfulfillment. The model finds the highest value of unfullfillment across all shelters and seeks to reduce that value, thereby balancing the fill rate among all of the facilities.

The inclusion of several commodities and different transportation modes is looking to attain a more realistic scenario of the activities performed. Usually, authorities have to deliver different types of products and the characteristics of each one affects distribution, especially thinking about size and volume for storage and transportation. Talking about transportation, considering only one type of transportation mode can hinder the right solution given the need to obtain the best combination. For the Mexican case, authorities usually have road transportation along with boats for flooded areas and helicopters for inaccessible regions. The model is aiming to gather all of those together to find the right balance according to the objectives.

The core of the model is to decide the best policy in terms of the resources available. The need to balance efficiency and effectiveness is shared by the organisations involved, complementing each other to achieve the higher benefit for the system. The value of adding the activation/deactivation of the organisations is to balance the use of resources, because, as mentioned before, having too much sometimes can be almost as harmful as not having enough. This type of formulation is believed to allow the user to identify the organisations required given the resources available to each one of them.

Overall this model is including several dimensions in decision-making. Cost and level of service are optimised simultaneously. The geographical perspective including risk and potential damage are incorporated by the use of GIS. Coverage of facilities is added as a constraint to condition service between supply facilities and demand areas; whereas distance is integrated in service availability and indirectly affecting transportation cost. The number of organisations is seeking to provide the best possible service at the lowest cost. The result is a model considering the most common metrics used in the literature to provide an informed disaster management policy.

5.2.5 Notation and definitions

The sets, parameters and variables included in the model are presented as follows:

Sets

I	Candidate distribution centres, *I* = {1, 2, 3, …, *I)*
J	Candidate shelters, *J* = {1, 2, 3, …, *J)*
K	Demand areas, *K* = {1, 2, 3, …, *K)*
M	Transportation modes, *M* = {1, 2, 3, …, *M)*
N	Products, *N* = {1, 2, 3, …, *N)*
O	Organisations, *O* = {1, 2, 3, …, O*)*

Parameters

RPC	Space covered per distribution centre employee ($\frac{m^3}{employee}$)
RPS	Number of sheltered people covered per shelter employee ($\frac{people}{employee}$)
RPH	Number of people covered per healthcare team ($\frac{people}{team}$)
APDC	Percentage of personnel required for partial opening of DCs, $0 \leq APDC \leq 1$
CA_i	DC opening cost per facility *i* ($), $i \in I$
CC_j	Shelter opening cost per facility *j* ($), $j \in J$
CP_n	Procurement cost per product *n* ($\frac{\$}{product}$), $n \in N$
C_j	Capacity of shelter *j* (people), $j \in J$
A_i	Capacity of distribution centre *i* (m^3), $i \in I$

VOL_n	Volume per product *n* ($\frac{m^3}{product}$), $n \in N$
WEI_n	Weight per product *n* ($\frac{kg}{product}$), $n \in N$
PAC_o	Available personnel from organisation *o* for DC operation (employee), $o \in O$
PAS_o	Available personnel from organisation *o* for shelter operation (employee), $o \in O$
PAH_o	Available teams from organisation *o* for healthcare (team), $o \in O$
PAD_o	Available personnel from organisation *o* for distribution (employee), $o \in O$
TP_o	Total operative personnel available per organisation *o* (employee), $o \in O$
G_n	Conversion factor for each product *n* ($\frac{people}{product}$) , $n \in N$
$TIER_n$	Priority of product *n*, $n \in N$
EP_k	Population to be sheltered per demand area *k* (people), $k \in K$
F_m	Weight vehicle capacity of mode *m* ($\frac{kg}{trip}$) ,$m \in M$
AVD_m	Available number of trips per day per mode *m* ($\frac{trips}{vehicle}$) ,$m \in M$
RDP_m	Distribution personnel required per mode *m* (employees/vehicle) ,$m \in M$
$WAGE_o$	Wages paid for the activation of organisation *o* ($), $o \in O$
CS_{ijm}	Cost of delivering relief from DC *i* to shelter *j* by mode *m* ($\frac{\$}{trip}$), $i \in I$, $j \in J$, $m \in M$
IP_{no}	Product inventory of type *n* from organisation *o* available (products), $n \in N$, o $\in O$
CON_{ijm}	Connectivity between DC *i* and shelter *j* by mode *m*, $con_{ijm} \in [0,1]$, $i \in I$, $j \in J$, $m \in M$
TV_{mo}	Total number of vehicles available of type *m* per organisation *o* (vehicles), $m \in M$, o $\in O$
SA_{ijm}	Service availability for relief distribution from DC *i* to shelter *j* by mode *m* based on coverage, $SA_{ijm} \in [0,1]$, $i \in I$, $j \in J$, $m \in M$
SC_{kj}	Coverage of demand area *k* from shelter *j*, $SC_{kj} \in [0,1]$, $j \in J$, $k \in K$

Intermediate variables

$TRAV_{ijm}$	Number of trips deployed from DC *i* to shelter *j* by mode *m* (trips)
IPD_{jn}	Number of products of type *n* required at shelter *j* (products)
$DSAT_{jn}$	Demand of product *n* not fulfilled on shelter *j* (products)

$DISP_{kj}$	Number of people to be allocated from demand zone *k* to shelter *j* (people)
NVH_j	Expected number of people without healthcare at shelter *j* (people)
PVH_j	Surplus of people covered for healthcare at shelter *j* (people)
NVS_j	Expected number of people without shelter attention at shelter *j* (people)
PVS_j	Surplus of people covered for shelter attention at shelter *j* (people)
MAD_j	Maximum number of people with relief shortages at shelter *j* (people)
D_j	Number of people to be allocated to shelter *j* (people)
UFR	Maximum unfulfilled demand
Cost	Total cost ($)

Decision variables

X_i	Whether to open DC *i* or not
Y_j	Whether to open shelter *j* or not
W_o	Whether to activate organisation *o* or not
PRE_{ino}	Quantity of stock of product *n* from agency *o* to preposition on DC *i* (products)
$SHIP_{ijmn}$	Amount of relief of type *n* delivered from DC *i* to shelter *j* by mode *m* (products)
PC_{io}	Number of personnel from organisation *o* to be allocated to DC *i* (employee)
PS_{jo}	Number of personnel from organisation *o* to be allocated to shelter *j* (employee)
PH_{jo}	Number of teams from organisation *o* to be allocated for healthcare to shelter *j* (team)
PD_{imo}	Number of personnel from organisation *o* to be allocated for distribution to DC *i* (employee)
AV_{imo}	Number of vehicles of type *m* from organisation *o* to be allocated at DC *i* (vehicles)

5.2.6 Model formulation

A relevant aspect of the model designed is the multi-organisational perspective. By including the agencies as a set, data from each individual agent can be introduced for the model to find the best combination by first deciding whether the activation of an agency is justified or not, and then how to use the material and human resources available. This approach includes only necessary agencies and coordinates them through the allocation of tasks to each actor, whereas current models with one actor work under the assumption of activating every agency available, leaving task and resource allocation to other decision mechanisms. The alternative is to run one model for each agency, hence hindering coordination. We believe our approach allows more flexibility for planning and preparedness for large-scale and small-scale disasters, and the clear allocation of activities would enhance collaboration and coordination. The model is structured as follows:

$$Min\ COST = \sum_i CA_i * \boldsymbol{X_i} + \sum_j CC_j * \boldsymbol{Y_j} + \sum_o WAGE_o * \boldsymbol{W_o} + \sum_i \sum_n \sum_o CP_n * \boldsymbol{PRE_{ino}} + \sum_i \sum_j \sum_m CS_{ijm} * TRAV_{ijm} \quad (1)$$

$$Min\ UFR = \max_{j \in J} \left(\frac{(MAD_j + NVH_j + NVS_j)}{3 * C_j}\right) * 100\% \quad (2)$$

s.t

$$D_j = \sum_k DISP_{kj} \qquad \forall j \quad (3)$$

$$EP_k = \sum_j DISP_{kj} * SC_{kj} \qquad \forall k \quad (4)$$

$$IPD_{jn} * G_n \geq D_j \qquad \forall j, n \quad (5)$$

$$DSAT_{jn} = IPD_{jn} - \sum_i \sum_m \boldsymbol{SHIP_{ijmn}} \qquad \forall j, n \quad (6)$$

$$MAD_j \geq \frac{\sum_n DSAT_{jn} * G_n * TIER_n}{\sum_n TIER_n} \qquad \forall j \quad (7)$$

$$D_j \leq C_j * \boldsymbol{Y_j} \qquad \forall j \quad (8)$$

$$\sum_n \sum_o \boldsymbol{PRE_{ino}} * VOL_n \leq A_i * \boldsymbol{X_i} \qquad \forall i \quad (9)$$

$$\sum_i \boldsymbol{PRE_{ino}} = IP_{no} * \boldsymbol{W_o} \qquad \forall n, o \quad (10)$$

$$\sum_j \sum_m \boldsymbol{SHIP_{ijmn}} \leq \sum_o \boldsymbol{PRE_{ino}} \qquad \forall i, n \quad (11)$$

$$APDC * A_i * \boldsymbol{X_i} \leq RPC * \sum_o \boldsymbol{PC_{io}} \qquad \forall i \quad (12)$$

$$D_j = RPH * \sum_o \boldsymbol{PH_{jo}} + NVH_j - PVH_j \qquad \forall j \quad (13)$$

$$D_j = RPS * \sum_o \boldsymbol{PS_{jo}} + NVS_j - PVS_j \qquad \forall j \quad (14)$$

$$\sum_i \boldsymbol{PC_{io}} \leq PAC_o * \boldsymbol{W_O} \qquad \forall o \quad (15)$$

$$\sum_j \boldsymbol{PS_{jo}} \leq PAS_o * \boldsymbol{W_o} \qquad \forall o \quad (16)$$

$$\sum_j \boldsymbol{PH_{jo}} \leq PAH_o * \boldsymbol{W_o} \qquad \forall o \quad (17)$$

$$\sum_i \sum_m \boldsymbol{PD_{imo}} \leq PAD_o * \boldsymbol{W_o} \qquad \forall o \quad (18)$$

$$TP_O * \boldsymbol{W_O} \geq \sum_i \boldsymbol{PC_{io}} + \sum_j \boldsymbol{PS_{jo}} + \sum_j \boldsymbol{PH_{jo}} + \sum_i \sum_m \boldsymbol{PD_{imo}} \qquad \forall o \quad (19)$$

$$\sum_n \boldsymbol{SHIP_{ijmn}} * WEI_n \leq F_m * TRAV_{ijm} * CON_{ijm} * SA_{ijm} \qquad \forall i, j, m \quad (20)$$

$$\sum_j TRAV_{ijm} \leq \sum_o \boldsymbol{AV_{imo}} * AVD_m \qquad \forall i, m \quad (21)$$

$$\boldsymbol{AV_{imo}} \leq \frac{\boldsymbol{PD_{imo}}}{RDP_m} \qquad \forall i, m, o \quad (22)$$

$$\sum_i \boldsymbol{AV_{imo}} \leq TV_{mo} * \boldsymbol{W_o} \qquad \forall m, o \quad (23)$$

$$X_i, Y_j, W_o \in \{0,1\}$$

$$PRE_{ino}, TRAV_{ijm}, D_j, DISP_{kj}, IPD_{jn}, DSAT_{jn}, SHIP_{ijmn}, PH_{jo}, PC_{io}, NVH_j, NVS_j, PVH_j, PVS_j, MAD_j, PS_{jo}, PD_{imo}, AV_{imo} \in Z_{\geq 0}$$

Objective function (1) seeks to minimise costs associated with the location of facilities, personnel, procurement and transportation, whereas objective function (2) minimises the maximum unfulfillment of products and services across all the shelters as a measure of equity. Constraint (3) determines demand of people at each shelter and expression (4) ensures that every evacuee reaches a shelter. Equation (5) determines demand per product at each shelter, whereas expression (6) establishes unfulfilled demand and constraint (7) determines the maximum demand unsatisfied across the different products per shelter. Expressions (8) and (9) deal with the capacity of shelters and DCs respectively, whereas constraint (10) determines the maximum amount available of relief items to preposition available across all agencies and equation (11) ensures that only relief items available are shipped. Constraint (12) allows the partial opening of DCs and determines the number of people required, whereas expressions (13) and (14) determine the number of personnel and shortages for healthcare and shelter care respectively. Equations (15), (16), (17) and (18) establish the maximum number of personnel available across all agencies for DCs, shelters, healthcare and distribution respectively; whereas constraint (19) ensures that the maximum number of operative people per organisation activated is not bridged including the term for healthcare teams if and only if one member is available for operative support such as the distribution of medicines. Expression (20) determines the number of trips from each DC to each shelter for distribution, constraint (21) establishes the number of vehicles required, equation (22) the number of people for distribution needed and expression (23) bounds the maximum number of vehicles available. Finally, the declaration of binary and integer variables is presented.

5.2.7 Model solution

The use of more than one performance measure does not yield a unique optimal solution but a set of efficient solutions that can be depicted in the Pareto frontier. To obtain the set of efficient solutions, there are three common techniques: a priori, a posteriori and interactive (Zio and Bazzo, 2012). A priori methods are applied when the preferences are known before the model is solved; the purpose is to try to fulfil those expectations (Miettinen, 2008). Among a priori methods, a lexicographic approach was discarded because there was no ranking between the objectives (Ehrgott, 2005), i.e. none of the performance measures was considered to be significantly more important than the other. Goal programming was discarded as well because obtaining a threshold for fill rate and specially cost from authorities can be problematic for major disasters, as it is very complicated to foresee an 'adequate' value and it is subject to the possibility of having 'optimistic' or 'pessimistic' decision makers (Miettinen, 2008).

Interactive methods use an iterative solution algorithm with repetitive steps updating the preferences of the decision-maker on every stage to find the solution (Miettinen et al., 2008).

Nonetheless, as the decision-maker is not available for this research an a posteriori approach is undertaken. The purpose of the a posteriori approach is to first generate the Pareto frontier and then ask the decision-maker to find the preferred solution from them (Miettinen, 2008). Even though this method can be computationally expensive and difficult, it is chosen because it is considered that having the frontier can provide a better overview of the possibilities and inform the solution (Miettinen, 2008). Scalarization techniques are a traditional approach to solving these kind of problems (Ehrgott, 2005) by replacing a vector problem into a family of scalar optimisation problems (Huong and Yen, 2014). From the scalarization techniques available, the weighted-sum method and the ε-constraint method were selected for this research. The former is selected because of simplicity and accuracy (Miettinen, 2008), although there is a well-known limitation to obtain solutions for non-convex problems (Ehrgott, 2005). The weighted-sum method is complemented with the ε-constraint method, which is also a very applied method and does not have limitation about convexity (Miettinen, 2008).

The overall solution procedure is as follows. The Pareto frontier will be generated using the weighted-sum method and the ε-constraint method. The models can be programmed on GAMS® using Cplex® *as a solver. Then, the Pareto frontier is taken* to the decision-maker, in order to explain to him/her the concept of *trade-off* and search for the solution that is closer to his/her preferences. Once a decision maker finds an attractive point, the information about the policy should be displayed for assessment, and the possibility to move to another solution on the frontier offered until the decision-maker is satisfied with the solution.

5.2.8 Verification and validation

Considering the ideas from Ronchi et al. (2014), the preparedness optimisation model was verified. Initially, after programming the model in GAMS®, the code was checked to avoid any mistakes. Afterwards, the model was re-checked to ensure the equations were equivalent to the theoretical model designed.

The author suggests preparing a set of hypothetical test cases to assess different situations. In that sense, a search for databases containing standard pre-solved problems available for comparing and assessing models, such as the ones available for routing or assessing heuristics, was performed. Unfortunatelly, there seems to be an absence of standardised models in the literature of humanitarian logistics for the problems at hand. That creates a complication in terms of comparison of the models in the field, as there is no reference point to allow authors to compare and contraste their contribution against existing works in the literature. It is understandable that each new model in the field is looking into different features, but there is a need of benchmark data to be able to provide sound arguments to assess new models.

Given the lack of benchmark data for analysis, a example was created in order to compare the results to the expected outcome for the situation. As the model required a large database and the number of combinations could complicate the manual solution, a small excercise was used with the following features:

- Candidate DCs: 2
- Candidate shelters: 4
- Demand areas: 3
- Transportation modes: 2
- Products: 2
- Agencies: 2

The model was solved initially using a set of random parameters. The result obtainde from GAMS® using the weighted-sum method was compared to the analytical result obtained manually. As the outcome for each one of the variables was accurate, the model was believed to be working as expected. Next, integer variables were changed to continuous variables and vice versa, having as a result variations in the value of the performance measures and variables. The complete evaluation of every constraint in the last verification performed can be checked on Appendix A. For previous analysis the reader is referred to the author.

Afterwards, each constraint was analysed by making changes on the input data and evaluating the effect on the result of the model. The idea was to change parameters to test the changes on the constraints and verify the possibility of unfeasibility. For instance, the capacity of shelters was changed, the number of evacuated people, capacity of DCs, number of personnel available per activity, and number of vehicles available.

After checking that the behaviour was consistent with the expected results from the design stage, the Min – Max approach was analysed by changing sistematically the overall demand and facilities available to check that the model was trying to achieve equity accross all shelters for each case.

Finally, the model was divided in five components: evacuation, sheltering, prepositioning, distribution, and resource allocation. Then, constraints related to each one of the components were relaxed to see the overall effect on the model and also the dependencies between the activities. The links created in the model were tested to look for redundancy of constraints and the appropriate relationship between the elements included.

On the other hand validation can be more difficult because the definition has been considered ambiguous in terms of the required level of accuracy the model should attain (Ronchi et al., 2014). Common validation methods explained by Sargent (2013) and

Robinson (1997) are difficult to adapt to the models used. As explained before, there is a lack of benchmarks in the literature to compare the preparedness optimisation model to other models in the literature. Considering that complication, face validity was used as presented on Table 4.5, using input from different academic and practical forums to assess the model. Also, parameter variability and extreme condition test (See Sargent, 2013) were used to make sure the model was not performing in an absurd manner.

5.3 Response model

After the conditions of the disaster are better known, different organisations can plan the activities to perform for the rest of the emergency situation. The role of the response model developed in this dissertation is to provide aid on decision making for that interval of time. The model includes two objective functions similar to the ones introduced on the preparedness model, but with constraints related to inventory levels, supply requirements, allocation of resources, activation/deactivation of agencies and allocation of distribution. A crucial difference between the preparedness model and the response model is the dynamic nature of the latter. According to the situation, the decision-maker establishes the number of periods in which the assistance to victims is going to be provided before the recovery stage, and the model can create a plan for the rest of the emergency. That adds a new dimension to the management of organisations, as now the model can determine not only what actors to involve but also when.

5.3.1 Model assumptions

The assumptions considered for the development and application of the response model can be defined as:

- There is one overarching decision-maker authority in charge of creating the preparedness plan and coordinating the other organisations.
- The variables included in the model are deterministic.
- The agencies involved can be deployed and deactivated at any stage.
- The location and number of facilities are determined previously either with the preparedness model or another method employed by authorities.
- Each shelter has a storage capacity according to the capacity of people. Demand areas outside of shelters are considered to have no storage capacity.
- Once an agency is activated, relief owned by that agency can be delivered by any agency.
- The activation of an agency yields the payment in full of the payroll of every member of the organisation.

- Transportation costs are only dependent on the fuel spent to perform the delivery. Vehicles are pre-owned by the organisations involved, leaving depreciation aside.
- The initial resources to cope with the emergency are deployed before the application of the response model, giving a preparation period for the response plan.
- Routing can be performed using one of the algorithms found in the literature (See Golden et al., 2008, Toth and Vigo, 2007) or the expertise from local drivers (de la Torre et al., 2012).
- There is no quantifiable holding cost.
- Both objectives are relevant for the decision maker and there is no clear dominance from one over the other.
- Demand over the planning period can be forecasted.
- Supply is considered to be reliable and consistent as forecasted by authorities.

These assumptions underpin the design of the model and were established according to the literature and discussions between the people involved in the project.

5.3.2 Data requirements

Most of the data required is very similar to the information already used for the preparedness model, making data collection easier. The information necessary for the application of the response model is:

- The list of DCs along with their storage capacity and location.
- The list of shelters along with their storage capacity, type, location and demand per period.
- The list of transportation modes including type, capacity, fuel consumption and required number of people per vehicle.
- The list of commodities including their size, weight, level of priority, cost and number of people served per unit.
- The list of agencies including the number of people available per activity per period, the number and type of vehicles available per period, the supply capacity of each product per period, and the wages associated with each one of them per period.
- Personnel requirements for the management of DCs, shelters, healthcare and distribution, along with the initial allocation of personnel.
- Trips per day per mode determined based on working hours, docking time and loading-unloading time.
- Shipment cost, coverage availability and connectivity per period from each distribution centre to each shelter.
- Threshold for shelter coverage with respect to the demand areas and threshold for minimum fill rate per shelter every three periods.

- Initial conditions in terms of the agencies already activated and relief items available per facility.

The information to collect beyond the requirements of the preparedness model is related to demand of people and items, the type of facilities used, storage capacity, threshold for minimum fill rate per shelter every three periods, and initial allocation of resources. Also extra information should be collected for multiple periods of time on some data.

5.3.3 Model justification

The response model is incorporating deterministic variables, bearing in mind that uncertainty in the transportation network is still tackled with results from the GIS and supply is assumed to be reliable and consistent. Regarding demand uncertainty, the model was designed to be used after the disaster strikes the region, having the initial stage covered by the preparedness model to gather information and forecast demand according to the expected duration of the disaster, reducing the level of uncertainty. Besides, the use of the GIS and the preparedness model can reduce the chance of facility disruption.

The model is dynamic in nature, meaning that several periods are considered. The decisions from one period are affecting adjacent periods, aiming to consider the evolution of events from one period to another. For instance, the deprivation cost function developed by Holguín-Veras et al. (2013) can only be used in a dynamic model because it is considering the exponential variation from one period to another without the fulfilment of demand. The response model is designed under the idea that is important to control the variables with relation to the events on adjacent periods.

The purpose of the response model is to balance efficiency and effectiveness (See Beamon and Balcik, 2008) with a component of equity, in line with key indicators for public services (Savas, 1978). The literature review showed that the use of multi-objective models for relief distribution and resource allocation have provided interesting results (e.g. Huang et al., 2015, Liberatore et al., 2014, Tirado et al., 2014, Ortuño et al., 2011). Hence, the model considers two objective functions which are related to cost and fill rate. Cost is considered from the perspective of the authorities as a key indicator (Rodríguez-Espíndola and Gaytán, 2015, Rodríguez-Espíndola, 2011) and used as a measure of efficiency (Beamon and Balcik, 2008).

Fill rate incorporates the perspective of the victims and it is employed as a proxy for the level of service provided to people in three dimensions: the fulfilment of relief items, the presence of healthcare personnel for injuries and diseases, and the presence of shelter personnel to deal with security, cooking, leisure, among others; components of the assistance provided by Mexican authorities in shelters (SEDENA, 2010, SSPPC, 2014d). In this case an index is not desired because each period is independent; for instance 100% of satisfaction in one period could be 10 people and 60% on another 500 people. Then, the model could be focusing on the periods of low demand to improve the solution but with a poor performance overall. In order to avoid that from happening, the fill rate objective function on the response model is an aggregated measure across all shelters and all periods.

Accepting the premise that deprivation increases exponentially (Holguín-Veras et al., 2013), one of the constraints of the model uses a value determined by the decision-maker ensuring a percentage of demand is fulfilled in the combination of three periods, maintaining constant supply for all of the demand points. The model is able to handle shelters and demand areas for distribution, making equity for the response model the provision of a similar fulfilment rate for all demand points over three periods.

Regarding the rest of the constraints, most of them are similar as the ones presented on the preparedness model for distribution, allocation of resources, and fulfilment of demand; being extended for multiple periods. The partial operation of DCs is also considered for cases where authorities have limited resources or the situation does not require the full opening of these facilities. The inclusion of a parameter related to the type of facility is because there are different types of floods, and for small-scale episodes people might remain on their homes. There can be cases where authorities want to use the model to perform distribution to areas outside the shelters. These additional demand points can be managed by the model by incorporating artificial points for distribution. In addition, constraints related to supply and inventory levels have been added accordingly with the goals of the model.

The activation/deactivation of organisations represents an important aspect for the response model. This model is not only deciding how many and which organisations are involved in disaster management, but also when are these organisations required. Similarly to the preparedness model, having centralised coordination allows the response model to integrate organisations regardless of their affiliation, meaning that non-governmental organisations can be incorporated and considered equally as any governmental organisation.

5.3.4 Design rationale

The response model makes the decisions included on Table 5.4 in order to provide support throughout the flood situation. Based on the expected results, a bi-objective mixed-integer optimisation model was designed. Efficiency is based on the minimisation of procurement cost, expenses of the activation of an agency and transportation cost, whereas effectiveness is obtained by minimising the aggregated unfulfillment of healthcare, shelter attention and the provision of relief items. Shelter care and healthcare coverage are determined using expert knowledge from authorities.

Table 5.4 Decisions taken by the response model

Decision	Decision
Personnel used for each activity per period	Service allocation for distribution per period
Agencies involved per period	Allocation of personnel per period
Inventory levels at shelters per period	Personnel rotation
Inventory levels at DCs per period	Shipment quantities and allocation per period
Allocation of vehicles per period	Transport mode selection

The model is aiming to reach as many people as possible as an objective, but it is constrained by a minimum threshold of fill rate. The idea is to ensure a lower bound of satisfaction at each shelter over three periods, which is determined by the decision-maker according to his/her preferences and the situation.

The threshold constraint is a major component of the model, as its effect affects directly the result obtained. Trying to provide a similar level of service across demand areas is complicated when several periods of time are involved. The equity constraint integrated in the model is looking to achieve that by providing a minimum fill rate per product to be fulfilled at every one of the demand areas. The constraint compares a value suggested by the decision maker with the total consumption of each product at each demand area divided by the total demand at that facility over three periods. That way, the consumption has to be at least enough to accomplish the level proposed by the decision maker. The constraint was designed considering the deprivation function proposed by Holguín-Veras et al. (2013) along with the potential unfeasibility issues associated with requesting a percentage of satisfaction per period. As there can be periods with large supply and others with low supply, the idea is to balance the resources available to provide a certain percentage of relief with the flexibility of having three periods to satisfy the constraint, aiming to maintain constant flow to all of the demand zones. The constraint is a main driver for the model and it can produce unfeasibility if the threshold is set too high. Also, putting high values for every product can be counterproductive in terms of solution time, as the threshold constraint is a hard constraint that enforces the model to disregard any solution that is not achieving the fill rate introduced by the decision-maker.

The inclusion of several commodities and different transportation modes is considered relevant for a model on the response stage in order to provide better aid for decision-making.

The response model is allowing the decision-maker to realise the right moment to start deactivating some agencies because of the changes in the situation, such as when demand is expected to start decreasing. That new dimension is particularly important for large and resourceful agencies that have deployed considerable resources and need to recover for any other event or activities.

5.3.5 Notation and definitions

The sets, parameters and variables included in the model are presented as follows:

Sets

I	Supply facilities, *I* = {1, 2, 3, …, *I)*
J	Demand areas, *J* = {1, 2, 3, …, *J)*
M	Transportation modes, *M* = {1, 2, 3, …, *M)*
N	Products, *N* = {1, 2, 3, …, *N)*
O	Organisations, *O* = {1, 2, 3, …, *O)*
T	Periods of time, *T* = {1, 2, 3, …, *T*)

Parameters

RPC	Space covered per distribution centre employee ($\frac{m^3}{employee}$)
RPS	Number of people covered per shelter employee ($\frac{people}{employee}$)
RPH	Number of people covered per healthcare team ($\frac{people}{team}$)
APDC	Percentage of personnel required for partial opening of DCs, $0 \leq APDC \leq 1$
OND	Number of days for relief distribution per period (day)
CP_n	Procurement cost per product *n* ($\frac{\$}{product}$), $n \in N$
CI_j	Storage capacity of shelter *j* (m^3), $j \in J$
A_i	Capacity of DC *i* (m^3), $i \in I$
$Type_j$	Type of demand area, $type_j \in [0,1]$
VOL_n	Volume per product *n* ($\frac{m^3}{product}$), $n \in N$
WEI_n	Weight per product *n* ($\frac{kg}{product}$), $n \in N$
PAC_{ot}	Available personnel from organisation *o* for DC operation at period *t* (employee), $o \in O$, $t \in T$
PAS_{ot}	Available personnel from organisation *o* for shelter operation at period *t* (employee), $o \in O$, $t \in T$
PAH_{ot}	Available personnel from organisation *o* for healthcare at period *t* (team), $o \in O$, $t \in T$
PAD_{ot}	Available personnel from organisation *o* for distribution at period *t* (employee), $o \in O$, $t \in T$
TRP_{ot}	Total operative personnel available per organisation *o* at period *t* (employee),

$o \in O, t \in T$

G_n	Conversion factor for each product *n* ($\frac{people}{product}$) , $n \in N$
PRI_n	Priority of product *n*, $n \in N$
SL_n	Minimum threshold for demand satisfaction of product *n* every three periods, $0 \leq SL_n \leq 1$
D_{jt}	Number of people aided in demand area *j* at time *t* (people) $j \in J$, $t \in T$
EP_k	Population to be sheltered per demand area *k* (people), $k \in K$
F_m	Weight vehicle capacity of mode *m* ($\frac{kg}{trip}$) ,$m \in M$
AVD_m	Available number of trips per day per mode *m* ($\frac{trips}{vehicle}/day$) ,$m \in M$
RDP_m	Distribution personnel required per mode *m* ($\frac{employee}{vehicle}$) ,$m \in M$
$WAGE_{ot}$	Wages paid for the activation of organisation *o* at period *t* ($), $o \in O$, $t \in T$
CS_{ijm}	Cost of delivering relief from DC *i* to shelter *j* by mode *m* ($\frac{\$}{trip}$), $i \in I$, $j \in J$, $m \in M$
IPD_{jnt}	Product demand at demand point *j* of product type *n* at period *t* (products), $j \in J$, $n \in N$, $t \in T$
CON_{ijmt}	Connectivity between DC *i* and shelter *j* by mode *m* at period *t*, $con_{ijm} \in [0,1]$, $i \in I$, $j \in J$, $m \in M$, $t \in T$
TV_{mot}	Total number of vehicles available of type *m* per organisation *o* at period *t* (vehicles), $m \in M$, $o \in O$, $t \in T$
SA_{ijm}	Service availability for relief distribution from DC *i* to shelter *j* by mode *m* based on coverage, $SA_{ijm} \in [0,1]$, $i \in I$, $j \in J$, $m \in M$
SC_{not}	Supply capacity of product *n* from organisation *o* at period *t* (products), $n \in N$, $o \in O$, $t \in T$
$DI0_{inot}$	Initial inventory of product *n* from organisation *o* at DC *i* at period *t* (products), $i \in I$, $n \in N$, $o \in O$, $t \in T$
$SI0_{jnot}$	Initial inventory of product *n* from organisation *o* at demand point *j* at period *t* (products), $j \in J$, $n \in N$, $o \in O$, $t \in T$
$PC0_{iot}$	Initial personnel from organisation *o* at DC *i* at period *t* (employee), $i \in I$, $o \in O$, $t \in T$
$PS0_{jot}$	Initial personnel for shelter care from organisation *o* at shelter *j* at period *t* (employee), $j \in J$, $o \in O$, $t \in T$

$PH0_{jot}$ Initial personnel for healthcare from organisation *o* at shelter *j* at period *t* (team), $j \in J$, o $\in O$, $t \in T$

$PD0_{imot}$ Initial personnel for distribution from organisation *o* at DC *i* at period *t* (employee), $i \in I, m \in M$, o $\in O$, $t \in T$

Intermediate variables

$DSAT_{jnt}$ Demand of product *n* not fulfilled on shelter *j* at period *t* (product)

$TRAV_{ijmt}$ Number of trips deployed from DC *i* to shelter *j* by mode *m* at period *t* (trips)

NVH_{jt} Expected number of people without healthcare at shelter *j* at period *t* (people)

PVH_{jt} Surplus of people covered for healthcare at shelter *j* at period *t* (people)

NVS_{jt} Expected number of people without shelter attention at shelter *j* at period *t* (people)

PVS_{jt} Surplus of people covered for shelter attention at shelter *j* at period *t* (people)

APC_{iot} Increase of DC personnel from organisation *o* in facility *i* at period *t* (employee)

DPC_{iot} Decrease of DC personnel from organisation *o* in facility *i* at period *t* (employee)

APS_{jot} Increase of shelter personnel from organisation *o* in facility *j* at period *t* (employee)

DPS_{jot} Decrease of shelter personnel from organisation *o* in facility *j* at period *t* (employee)

APH_{jot} Increase of healthcare personnel from organisation *o* in facility *j* at period *t* (team)

DPH_{jot} Decrease of healthcare personnel from organisation *o* in facility *j* at period *t* (team)

APD_{imot} Increase of distribution personnel of mode *m* from organisation *o* in facility *i* at period *t* (employee)

DPD_{imot} Decrease of distribution personnel of mode *m* from organisation *o* in facility *i* at period *t* (employee)

MAD_{jt} Number of people with relief shortages at demand point *j* at period *t* (people)

TSC_{jnt} Amount of product *n* consumed at demand point *j* at period *t* (product)

INV_{jnt} Number of items of type *n* stored at demand point *j* at period *t* (product)

IL_{int} Number of items of type *n* stored at DC *i* at period *t* (product)

UFR Total unfulfilled demand (people)

Cost Total cost ($)

Decision variables

W_{ot} Whether to activate organisation *o* or not at period *t*

$SHIP_{ijmnt}$ Amount of relief of type *n* delivered from DC *i* to shelter *j* by mode *m* at period *t* (product)

PC_{iot} Number of personnel from organisation *o* to be allocated to DC *i* at period *t* (employee)

PS_{jot} Number of personnel from organisation *o* to be allocated to shelter *j* at period *t* (employee)

PH_{jot} Number of personnel from organisation *o* to be allocated for healthcare to shelter *j* at period *t* (team)

PD_{imot} Number of personnel from organisation *o* useful for mode *m* to be allocated for distribution to DC *i* at period *t* (employee)

AV_{imot} Number of vehicles of type *m* from organisation *o* to be allocated at DC *i* at period *t* (vehicles)

SUP_{inot} Amount of product *n* from organisation *o* supplied to DC *i* at period *t* (product)

5.3.6 Model formulation

The response optimisation model is looking to adequately use resources available during the whole flood. The model is allowed to choose which agencies to activate depending on the circumstances and also depending on the stage of the emergency, to design a policy tailored to the situation and the phase. The formulation of the bi-objective multi-commodity multi-modal multi-agency model is presented as follows:

$$Min\ Cost = \sum_{o}\sum_{t} \boldsymbol{W_{ot}} * WAGE_{ot} + \sum_{i}\sum_{n}\sum_{o}\sum_{t} CP_n * \boldsymbol{SUP_{inot}} + \sum_{i}\sum_{j}\sum_{m}\sum_{t} CS_{ijm} * TRAV_{ijmt} \quad (24)$$

$$Min\ UFR = \sum_j \sum_t (MAD_{jt} + NVH_{jt} + NVS_{jt}) \quad (25)$$

s.t.

$$MAD_{jt} = \frac{\sum_n DSAT_{jnt} * PRI_n * G_n}{\sum_n PRI_n} \qquad \forall j, t \quad (26)$$

$$DSAT_{jnt} = IPD_{jnt} - TSC_{jnt} \qquad \forall j, n, t \quad (27)$$

$$TSC_{jnt} + TSC_{jnt+1} + TSC_{jnt+2} \geq (IPD_{jnt} + IPD_{jnt+1} + IPD_{jnt+2}) * SL_n \qquad \forall j, n, t \quad (28)$$

$$IL_{int} = IL_{in(t-1)} + \sum_o \boldsymbol{SUP_{inot}} - \sum_j \sum_m \boldsymbol{SHIP_{ijmnt}} + \sum_o DI0_{inot} \quad \forall i,n,t \quad (29)$$

$$INV_{jnt} = INV_{jn(t-1)} + \sum_i \sum_m \boldsymbol{SHIP_{ijmnt}} - TSC_{jnt} + \sum_o SI0_{jnot} \quad \forall j,n,t \quad (30)$$

$$\sum_i \boldsymbol{SUP_{inot}} \leq SC_{not} * \boldsymbol{W_{ot}} \quad \forall n,o,t \quad (31)$$

$$A_i \geq \sum_n IL_{int} * VOL_n \quad \forall i,t \quad (32)$$

$$CI_j * TYPE_j \geq \sum_n INV_{jnt} * VOL_n \quad \forall j,t \quad (33)$$

$$APDC * A_i \leq RPC * \sum_o \boldsymbol{PC_{iot}} \quad \forall i,t \quad (34)$$

$$D_{jt} * TYPE_j \leq RPS * \sum_o \boldsymbol{PS_{jot}} + NVS_{jt} - PVS_{jt} \quad \forall j,t \quad (35)$$

$$D_{jt} * TYPE_j \leq RPH * \sum_o \boldsymbol{PH_{jot}} + NVH_{jt} - PVH_{jt} \quad \forall j,t \quad (36)$$

$$\boldsymbol{PC_{iot}} = \boldsymbol{PC_{io(t-1)}} + APC_{iot} - DPC_{iot} + PC0_{iot} \quad \forall i,o,t \quad (37)$$

$$\boldsymbol{PS_{jot}} = \boldsymbol{PS_{jo(t-1)}} + APS_{jot} - DPS_{jot} + PS0_{jot} \quad \forall j,o,t \quad (38)$$

$$\boldsymbol{PH_{jot}} = \boldsymbol{PH_{jo(t-1)}} + APH_{jot} - DPH_{jot} + PH0_{jot} \quad \forall j,o,t \quad (39)$$

$$\boldsymbol{PD_{imot}} = \boldsymbol{PD_{imo(t-1)}} + APD_{imot} - DPD_{imot} + PD0_{imot} \quad \forall i,m,o, \quad (40)$$

$$\sum_i \boldsymbol{PC_{iot}} = PAC_{ot} * \boldsymbol{W_{ot}} \quad \forall o,t \quad (41)$$

$$\sum_j \boldsymbol{PS_{jot}} = PAS_{ot} * \boldsymbol{W_{ot}} \quad \forall o,t \quad (42)$$

$$\sum_j \boldsymbol{PH_{iot}} = PAH_{ot} * \boldsymbol{W_{ot}} \quad \forall o,t \quad (43)$$

$$\sum_i \sum_m \boldsymbol{PD_{imot}} \leq PAD_{ot} * \boldsymbol{W_{ot}} \quad \forall o,t \quad (44)$$

$$TRP_{ot} * \boldsymbol{W_{ot}} \geq \sum_i \boldsymbol{PC_{iot}} + \sum_j \boldsymbol{PS_{jot}} + \sum_j \boldsymbol{PH_{jot}} + \sum_i \sum_m \boldsymbol{PD_{imot}} \quad \forall o,t \quad (45)$$

$$\sum_n \boldsymbol{SHIP_{ijmnt}} * WEI_n \leq F_m * TRAV_{ijmt} * CON_{ijmt} * SA_{ijm} \quad \forall i,j,m, \quad (46)$$

$$\sum_j TRAV_{ijmt} \leq OND * \sum_o \boldsymbol{AV_{imot}} * AVD_m \quad \forall i,m,t \quad (47)$$

$$\boldsymbol{AV_{imot}} \leq \frac{\boldsymbol{PD_{imot}}}{RDP_m} \quad \forall i,m,o, \quad (48)$$

$$\sum_i \boldsymbol{AV_{imot}} \leq TV_{mot} * \boldsymbol{W_{ot}} \quad \forall m,o,t \quad (49)$$

$$W_{ot} \in [0,1]$$

$$IL_{inot}, TRAV_{ijmt}, INV_{jnt}, DSAT_{jnt}, SHIP_{ijmnt}, PC_{iot}, PD_{imot}, AV_{imot}, APC_{iot},$$

$$DPC_{iot}, APD_{imot}, DPD_{imot,}, PH_{jot}, PS_{jot}, APH_{jot}, DPH_{jot}, APS_{jot}, DPS_{jot}, TSC_{jnt} \in Z_{\geq 0}$$

$$MAD_{jt} \in R^+$$

Expression (24) aims to use resources efficiently by minimising cost in terms of the number of organisations involved, procurement cost and transportation cost. Function (25) is considering the perspective of the victims by improving the level of service provided in terms of the minimisation of the total unfulfillment of shelter care, healthcare and relief distribution across all demand areas and all periods. Constraint (26) determines the unfulfillment level depending on the priority of the product from the number of unsatisfied demand established on equation (27). Expression (28) is enforcing that the combination of the consumption at every demand area of every product every three periods is at least a certain percentage of the total demand at all shelters over the same periods. Equations (29) and (30) determine the levels of inventory of DCs and demand areas, respectively. Expression (31) makes sure that items procured and delivered are aligned with the supply capacity from the organisations activated. Constraints (32) and (33) restrict the storage capacity of DCs and demand areas respectively. Expression (34) ensures a minimum number of personnel are allocated to DCs even for partial opening, whereas equations (35) and (36) determine the shortage or surplus of personnel for shelter attention and healthcare. Constraints (37), (38), (39) and (40) determine the number of personnel allocated for DC management, shelter care, healthcare and distribution including the rotation of personnel, whereas expressions (41), (42), (43) and (44) ensure the number of people allocated per activity does not surpass the availability of activated organisations. Equation (45) forces the number of operative resources used per agency to be lower than the number of personnel available, including the term for healthcare teams if and only if one member is available for operative support for distribution of medicines. Expression (46) determines the number of trips from each DC to each shelter for distribution, constraint (47) establishes the number of vehicles required, equation (48) the number of people needed, and expression (49) bounds the maximum number of vehicles available. Finally, the declaration of binary, continuous and integer variables is presented.

5.3.7 Model solution

The response model is solved using the weighted-sum method and the ε-constraint method with an a posteriori approach. The Pareto frontier is generated and used to find the best solution according to the preferences of the decision maker. After generating the Pareto frontier, the result is presented to the decision-maker in order to explain him/her the concept of *trade-off*, and search for the solution that is closer to his/her preferences. Once a decision maker finds an attractive point, the information about the policy is analysed offering the possibility to move to another solution until the decision-maker is satisfied with the solution.

5.3.8 Verification and validation

The response optimisation model was coded in GAMS®, checking the syntaxis to avoid any mistakes. Next, the model was re-checked to ensure the equations were equivalent to the theoretical model designed.

Departing from the suggestions from Ronchi et al. (2014), use of a hypothetical example was desired to verify the model. Unfortunately, as explained before, there is an absence of benchmark data in the literature to verify and validate the model at hand. As a result, an excerside was designed in order to compare the results to the expected outcome for the situation. As the model required a large database and the number of combinations could complicate the manual solution, a small example was used with the following features:

- Supply facilities: 2
- Demand areas: 4
- Transportation modes: 2

- Products: 3
- Agencies: 3
- Time periods: 5

The model was solved initially using a set of random parameters. The result obtainde from GAMS® using the weighted-sum method was compared to the analytical result obtained manually. The result from both sources was indentical, showing the model was behaving properly. Afterwards, integer variables were changed to continuous variables and vice versa, having as a result variations in the value of the performance measures and variables. The complete evaluation of every constraint in the last verification performed can be checked on Appendix B. For previous analysis the reader is referred to the author.

Then, each constraint was analysed by making changes on the parameters and assessing the effect on the outcome of the model. The variations in constraints were assessed and expected unfeasibility under certain circumstances was succesfully ratified. For example, the number of shelters was changed, the demand, the number of supply facilities, the number of time periods, capacity of DCs, number of personnel available per activity, and number of vehicles available.

After checking that the behaviour was consistent with the expected results from the design stage, threshold constraint was analysed. In this case, the values of the threshold were varied from 10% to 100% to notice the change in the result and verify the system was atually accomplishing the expected fill rate every three periods. In combination with changes on the supply capacity, unfesiability was tested and the increase in solution time due to complex combinations.

Afterwards, the model was divided in three components: inventory, distribution, and resource allocation. Constraints related to each one of the components were relaxed to see the overall effect on the model and also the dependencies between the activities. The links created in the model were tested to look for redundant constraints and verify the relationships between constraints.

Common validation methods explained by Sargent (2013) and Robinson (1997) are difficult to adapt to the response model as well. The absence of benchmarks in the literature to compare the response optimisation model to other models in the literature complicates appropriate validation. Also, the impossibility to control disasters in order to try the system make validation even more complicated. As a result, face validity was used as presented on Table 4.5, using input from different academic and practical forums to assess the response model. Also, parameter variability and extreme condition test (See Sargent, 2013) were used to make sure the model was not performing in an absurd manner.

5.4 Chapter Summary

This chapter has introduced the main components of the system designed to provide support on the stages of preparedness and response in flood situations. The geographical procedure was describes, along with relevant points for data gathering and preparation. The procedures on vector and raster GIS were explained, elaborating on the cartographic model implemented on IDRISI®. Afterwards, the two optimisation models were introduced, elaborating on the rationale and justification, the potential contribution provided, the mathematical presentation of them and the solution methods proposed.

Having introduced the system proposed, the next chapter is focused on its application to three case studies in Mexico, in order to provide an overview of the application procedure and analyse the results.

6 CASE STUDIES

Having introduced the main components of the system proposed, it is important to test it on different instances to have confidence on the reliability of the results. In that sense, contrasting the results with real conditions can be useful to study further the performance and applicability of the system designed. This chapter elaborates on the Mexican case studies used to analyse the performance of the system. The case studies were described on Table 4.4 and illustrated on Figure 6.1. Therefore, this section elaborates on the events and regions affected, data collection for the analysis, databases included, details about the application of the system, and results obtained.

Source: Compiled by author with information from Google_Earth (2014),

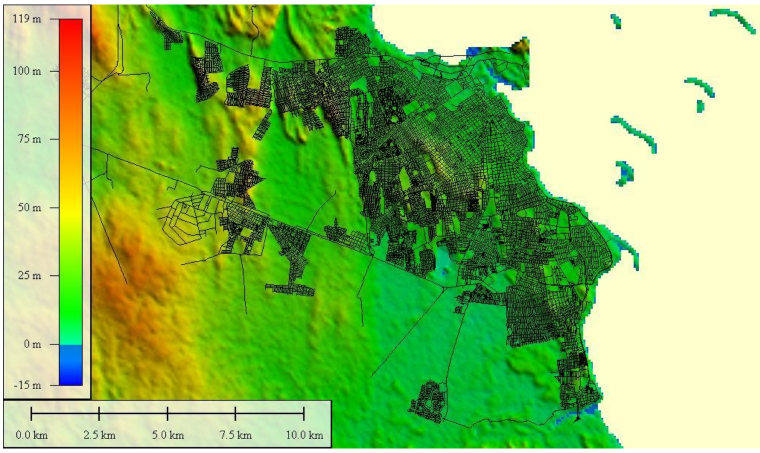
Figure 6.1. Location of the case studies in Mexico

The three cases were selected according to the conditions of the area and the event, seeking to provide different settings. Veracruz and Acapulco are coastal cities, whereas Villahermosa is located between a delta of three rivers, making the three areas prone to floods. Secondly, Acapulco is an international touristic attraction (INEGI, 2010a), whereas Veracruz is one of the most important international trading ports in the country (CAAAAREM, 2009), and Villahermosa is a significant axis of gas and oil activity (WECP, 2015). Veracruz represents a ‘small scale’ disaster event with 5,140 people sheltered, Acapulco a ‘medium scale’ event with 13,012 people sheltered, and Villahermosa a ‘large scale’ disaster sheltering around 99,000 people. The application of the system to the three cases is believed to provide robust results about performance under different circumstances and geographical regions.

6.1 Veracruz, Veracruz

Located at the centre of the State of same name, Veracruz has an altitude of 10 meters above sea level (INEGI, 2010a) and it is located on the coordinates 19° 12' north latitude and 96° 08' west longitude, 90 km away from the capital of the State (SEGOB, 2010). It is located in the hydrologic region Papaloapan with the basin R. Jamapa y Otros, experiencing an annual range of precipitation between 1,100 – 1,600 mm (INEGI, 2009b).

Figure 6.2 displays the image of the city and the road network is overlapping the map. The study focuses on the region Veracruz-Boca del Río. Boca del Río is a small section on the south divided from Veracruz by one road, and it contains part of the port of Veracruz. A total of 657,162 people lived in the region in 2010 (INEGI, 2010c).



Source: Compiled by author with information from USGS (2010) and INEGI (2010c)

Figure 6.2. Region Veracruz-Boca del Río

Veracruz is a relevant case because it is largest custom port in the Atlantic, representing in 2007 around 30% of the maritime trade in the country with around 258,280 operations (CAAAAREM, 2009). Veracruz has been affected by floods several times before, with terrible experiences on the floods of 1999 (Aguirre and Macías, 2006, Vázquez Conde et al., 2001) and 2010.

6.1.1 Conditions of the flood of 2010

Hurricane Karl reached peak intensity on September 17th (Stewart, 2011), around 80 km at the northeast of Veracruz with winds of 195 km/h (NASA, 2010b). It was the main cause of the flood in the region. Figure 6.3 shows the state of the hurricane on September 16th, exhibiting the extensive reach of the natural phenomenon.

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Source: NASA (2010b)

Figure 6.3. Aerial image from Hurricane Karl

Hurricane Karl caused 10-15 inch rainfall in half of Veracruz State as shown on Figure 6.4, generating severe floods and several deaths in the State (Stewart, 2011).

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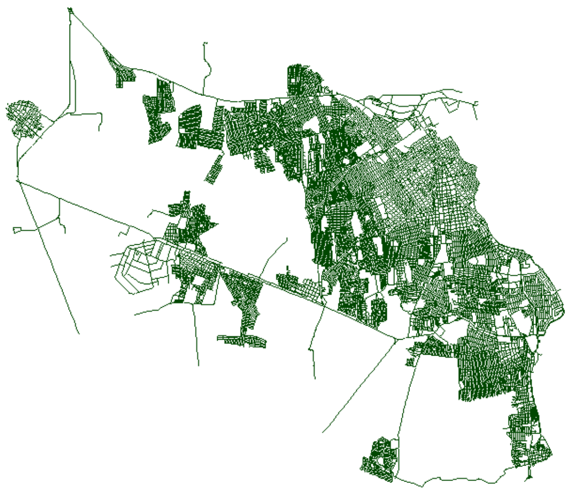
Source: David Roth, NOAA Hydro meteorological Prediction Centre cited on Stewart (2011)

Figure 6.4. Storm total precipitation associated to hurricane Karl

6.1.2 Application of the GIS procedure on Veracruz

6.1.2.1 Layers used for the case of Veracruz

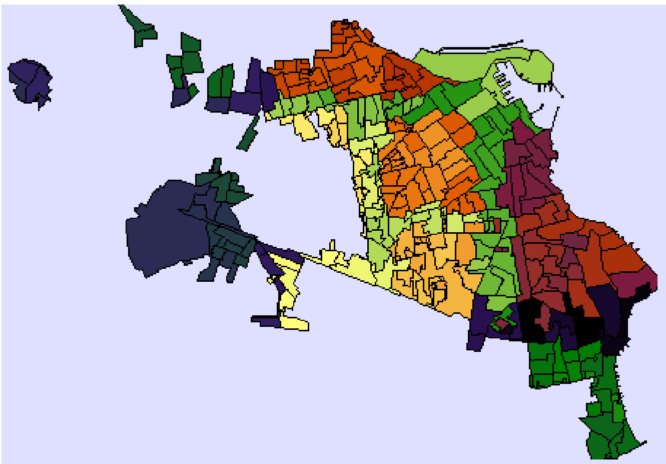
The first step to employ the cartographic model was the acquisition of the layers required. The road network and demand areas were obtained from INEGI (2010c) on format *shapefile*. Every image obtained from INEGI was imported directly into IDRISI® *from* NAD27 Lambert Conformal Conic projection. The road network is shown *on Figure 6.5, including all of the streets in the area.*



Source: Compiled by author with information from INEGI (2010c)

Figure 6.5. Road network of the region Veracruz-Boca del Río

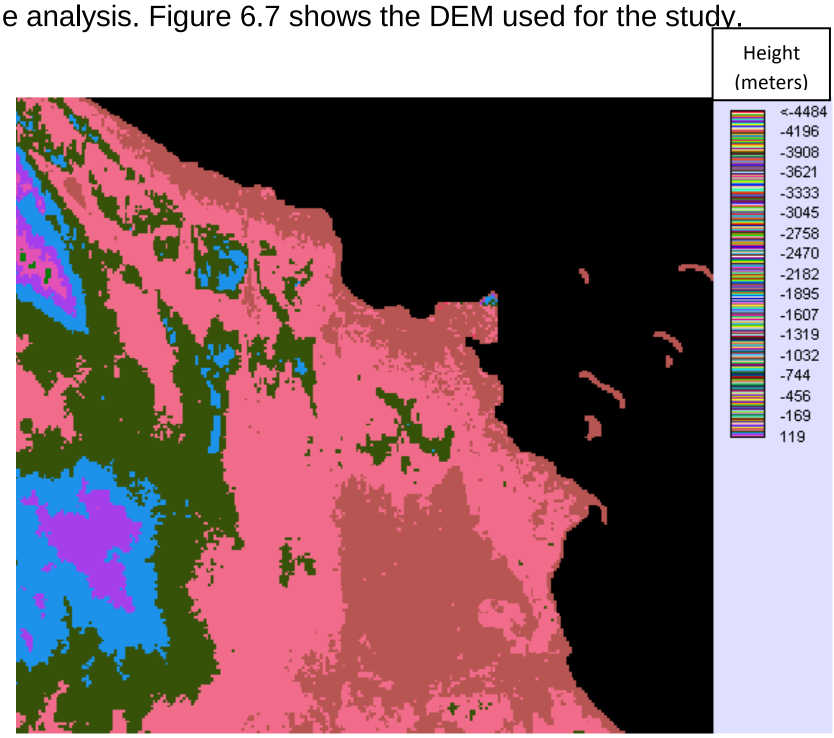
The unit selected for demand areas are AGEBs (from the Spanish Basic Geo-Statistic Areas). These units are considered by the Mexican government as an evolution of the neighbourhoods used some time ago. Each one of the AGEBs contains a database with the *number of inhabitants there along with an identifier. There are 315 of these units on the region under study as seen on Figure 6.6.*



Source: Compiled by author with information from INEGI (2010c)

Figure 6.6. AGEBs of the region Veracruz-Boca del Río

As the DEM is the baseline for the analysis, it was important to choose carefully which layer to use. Three DEMs of the area were acquired, two from INEGI (2015) and one from USGS (2010). One of the images from INEGI was discarded because it was based on a scale of 1:250,000, considered not accurate enough. The remaining image from INEGI was tested against the layer from USGS. In terms of reliability, the image from USGS showed to approximate better reality when comparing the measurements of each point with data from the real area obtained using Google Earth®. Also, the image from USGS showed more sensibility to variations of altitude below 1 meter. Therefore, the layer from USGS was selected for the analysis. Figure 6.7 shows the DEM used for the study.



Source: Compiled by author with information from USGS (2010)

Figure 6.7. Digital elevation model of the region Veracruz-Boca del Río

The final layers required are related to eligible facilities. Focusing on shelters available for the emergency, the information was provided by SEGOB (2014e). The shelter catalogue contained 589 facilities within the municipality. However, the information was incomplete. Some of the entries had no distinctive name, address nor coordinates, and many of the facilities were inside the municipality but outside of the city. Following the general guidelines given by SEDENA (2010), only schools were considered for the exercise along with facilities already identified by the agencies in the city. From the shelter catalogue, a total of 44 suitable facilities were found, including the 6 facilities already identified by authorities according to SSV (2014a), SEDENA (2014o) and PCV (2014c). All of the facilities are shown on Appendix D. The location of all the facilities for this dissertation was done by using the official website of the Ministry of Education (www.snie.sep.gob.mx/SNIESC/), identifying each school in TRANSCAD® and measuring the area of the buildings in the premises using Google Earth®. For the case of non-educational facilities, Google Maps®, *Bing Maps®* and physical coordinates along with the addresses were used to locate the facilities.

Similarly, facilities identified by authorities to serve by DCs were provided by SEDENA (2014r), DICONSA (2014f), PCV (2014f); whereas three facilities were identified according to the guidelines of SEDENA (2010). A total of ten available DCs were incorporated, which can be checked on Table D.2 in Appendix D.

Using the process for digitization explained in Section 5.1.2, the layers for both types of facilities were obtained. An overlap of the layer for shelters and the layer of distribution centres can be seen on Figure 6.8, displayed over the road network.

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Figure 6.8. Facilities available in the region of Veracruz-Boca del Río

6.1.2.2 GIS procedure for the case of Veracruz

The city and regions surrounding it are supposed to be 10 meters above sea level (INEGI, 2009b), however the importance of the baseline called to perform a manual analysis ranging from 0 to 10 meters to have reliable results. The baseline was determined at 6.5 meters. At this height, there is a significant change on the area when adding 0.5 meters, as it is supposed to happen when there is a flood. At lower values the variations are minimal.

The flood on in Veracruz is believed to have reached 1.5 meters of water level (AFP, 2010), which was used as the scenario for the real conditions. Also, a scenario with better conditions and another with worse conditions were analysed. Thus, floods of 0.5 meters and 2.5 meters were set for comparison. Applying the cartographic model introduced on Section 5.1.3, the results for the three scenarios are shown on Figure 6.9.

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Figure 6.9. Flood of 0.5 meters, 1.5 meters and 2.5 meters at Veracruz

6.1.2.3 Results of the GIS procedure applied to Veracruz

Figure 6.10 shows the candidate facilities surviving each one of the scenarios. Small red dots represent candidate shelters and cyan medium ones represent DCs.

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Figure 6.10. Surviving facilities for floods of 0.5 meters, 1.5 meters and 2.5 meters at Veracruz

From the above, Table E.1 on Appendix E displays the number of available shelters according to the flood depth of each scenario, whereas Table E.2 shows the number of available DCs. There were 43 surviving shelters and 9 DCs at a depth of 0.5 meters, 41 shelters and 9 DCs available with a water level of 1.5 meters, and 38 shelters and 8 DCs remaining for a situation of 2.5 meters of water. Overall, it can be seen that the impact of the flood on the facilities was low.

The damage of the floods on demand areas was estimated as follows: $Damage = \frac{A_i - A_f}{A_i} * 100\%$; being A_i the initial area without the flood and A_f the final dry area after the flood. Overall, the flood of 0.5 meters affected a nearly 21.6% of the total area, whereas the flood of 1.5 meters and 2.5 meters damaged around 25.4% and 32.7% of the region, respectively. Table 6.1 exhibits the number of AGEBs affected per level of damage after the flood for the three scenarios, ranging from not affected areas to AGEBS completely covered by water. Details about the damage caused per AGEB can be checked on Table E.3 of Appendix E.

Table 6.1. Number of AGEBs affected per percentage of damage

Percentage of damage	**0.5 m**	**1.5 m**	**2.5 m**	***Percentage of damage***	**0.5 m**	**1.5 m**	**2.5 m**
Not affected	247	235	212	*50<x<60*	1	6	5
1<x<10	22	21	28	*60<x<70*	2	7	8
10<x<20	13	11	11	*70<x<80*	3	1	9
20<x<30	8	7	9	*80<x<90*	1	4	5
30<x<40	6	7	8	*90<x*	8	10	15
40<x<50	4	6	5				

Using the flood map along with the road network, and employing the Floyd-Warshall algorithm presented on Section 5.1.3.3, the connectivity between facilities was obtained. For each facility four connected points were identified and the algorithm was run. The tables contain the value of 1 if there is at least one road available between the facilities and 0 otherwise. Air transportation was considered available between all facilities.

6.1.3 Preparedness optimisation model applied on Veracruz

Data for the preparedness optimisation model was collected from different authorities to run the model and obtain the set of efficient points.

6.1.3.1 Data collection for the scenarios on Veracruz

Using the national information transparency platform (https://www.infomex.org.mx/gobiernofederal/home.action) along with State transparency units, the author made a series of requests in the form of Freedom of Information (FOI) applications for data.

For the case of Veracruz a total of 62 requests were filed to a total of seven agencies involved in disaster management in the area, whereas 121 requests were made to ten National governmental bodies also involved in the flood. The selection of the agencies was performed using the information contained on Table 3.3. Some of the requests made to National agencies were specific about the flood on Veracruz and the others were asking for information about general guidelines in the country. The complete list of requests can be seen on Appendix C.

From the fourteen agencies identified, CENAPRED and the Ministry of External Affairs (SRE) were enquired about reports or international aid because of their not-operational nature. Excluding those agencies along with the Public Security Secretariat (SSP), Social Development Secretariat (SEDESOL) and the municipality, that claimed not to have information or jurisdiction, a total of nine operational agencies were identified as primary actors on the field. The agencies included were: DICONSA, National System of Family Development (DIF), Social Security Mexican Institute (IMSS), Civil protection (PC), National Health Ministry (SMEXICO), State Health Ministry of Veracruz (SVERACRUZ), SEDENA, Ministry of Interior (SEGOB) and the Navy (SEMAR).

Relief items

Using governmental suppliers, FONDEN is the main source of relief items in cases of disaster in Mexico. Table F.1 of Appendix F shows the items that can be delivered for disaster in Mexico, from which only food pantries are included in the preparedness model. The reason is because DICONSA only declared stock of that particular item (DICONSA, 2014a). The details regarding the products included in the food pantry can be seen on Tables F.2 and F.3 of Appendix F.

In terms of medicine, according to SS (2014f) Mexican authorities consider the use of one kit of medicines per 1,000 people per month (Health Ministry, personal communication 2nd September 2014). The contents of the kit can be seen on Table F.4 of Appendix F. Authorities have a centralized control over the kits and they break it down according to needs (Health Ministry, personal communication 2nd September 2014). However, for the model the assumption was that the kit for 1,000 people could be broken down to 10 kits for 100 people.

The features of the two items used for preparedness are displayed on Table 6.2.

Table 6.2. Features of the products used on the preparedness model

Item	People served	Replenishment	Weight (kg)	Volume (m^3)	Cost (MXN)
Food pantry	4	Every 4 days	7.468	0.024	176.06
Medicine kit	100	Every month	18.2	0.038052	2,566.37

Product inventory

The preparedness model considers the amount of stock available from different organisations to allocate it before the disaster. Each one of agencies involved was enquired about the amount of prepositioned stock available at the time of the flood. DICONSA (2014a) declared 2,500 food pantries prepositioned and no other items. Regarding medicines, SS (2014g) claimed the possession of two emergency kits for immediate response in the country, yielding a total of 20 kits for 100 people. Finally IMSS (2014b) stated a capacity of 2.2 months of stock, translated into 22 kits.

Shelters

The capacity of the facilities was obtained from the reports of the authorities and the list provided by SEGOB (2014e). Nonetheless, there were facilities without information about capacity. The capacity of these shelters was estimated according to the total building area measured with Google Earth®. Working under the assumption that 60% of the indoors area is used for dorms, the capacity was obtained dividing the dorms area by 3.5 m^2 as required on Table 5.1. This assumption was based on a trial on the schools Miguel Alemán and Benito Juárez.

Using the estimates and information about the relief items delivered by Mexican authorities, shelter cost was determined. DIF (2014b) provided information about cleaning costs for governmental buildings. The cleaning rate was Mexican pesos (MXN) $2.42/$m^2$. The cleaning cost was determined by multiplying the 'indoors' measurement of each facility times the cleaning cost per square meter.

In addition, shelters require having the basic commodities to receive people that are given just once. Mats, blankets and raincoats were considered individual items; thereby the cost was obtained by multiplying the capacity of the shelter times the cost per unit. Water containers and flashlights were assumed to be distributed per family; the cost of these items being obtained by multiplying the capacity of the shelter divided by four, times the cost of each item. According to INEGI (2010b), the number of people between 0 and 2 years represents 5.5% of the total population. Considering bathtubs can be re-used; it was decided to include one bathtub for every 100 people. Finally, the location cost was estimated as the sum of cleaning cost and the cost of the relief items described. The complete details along with the list of shelters included can be checked on Appendix D.

Demand

Demand estimation is outside of the scope of this research. There are some examples of models used in the literature (See Sheu, 2010, Cheng-An et al., 2010a, Mesa-Arango et al., 2013) that can be coupled with this system in order to provide a preparedness policy. Also, there are thresholds (See Shaw et al., 2011 pp. 79) that can be used to estimate not only the number of people evacuating, but also the number of people going to shelters.

For this work, the number of people by AGEB was obtained from INEGI (2010b) based on the census of 2010, which took place just before the disaster. Shelter demand for the real event was obtained from SSV (2014a), SEDENA (2014o) and PCV (2014c). The three organisations declared to be involved on sheltering people for the disaster, and the information was cross-referenced. For the cases when more than one agency managed a facility but declared a different number of people sheltered, the higher number was considered using a 'worst case' approach. A total of 5,140 people sheltered in the region was obtained. For the case of the other two scenarios, a lineal relationship between the flood depth and the number of people sheltered was assumed given the absence of any other information, leading to a total of 1,750 and 8,600 people for floods of 0.5 meters and 2.5 meters of depth, respectively.

To estimate the number of people evacuating per area results from the GIS procedure were used. The percentage of total population attending to shelters was obtained dividing the number of people sheltered per scenario by the total number of people in the area. Then, the number of people affected per area was obtained by multiplying the percentage of damage by the number of people in the zone. Finally, the percentage of people using shelters was multiplied times the number of people affected per demand area to obtain the number of people to serve per origin.

Distribution centres

Having the list of facilities, the capacity was obtained either from SEDENA (2014r) and DICONSA (2014f), or using a similar procedure to the one described for shelters. Cleaning cost was the only expense considered for setting-up DCs, and the values were obtained by multiplying the $\frac{cost}{m^2}$ times the area obtained from the measurement of the buildings inside the premises. Table D.2 on Appendix D shows the complete features of the DCs considered.

Transportation modes

The agencies involved were asked about the number, capacity and type of vehicles used in response to the flooding. Surprisingly, the number of agencies providing vehicles was higher than the number of agencies providing personnel. Leaving out cranes and ambulances, Table 6.3 summarises the number of vehicles available per organisation. Vehicles were classified on small trucks able to carry no more than 3.5 ton, medium trucks with a capacity of up to 8 tons, large trucks capable of handling more than 8 tons and helicopters.

Table 6.3. Vehicles available on Veracruz

Agency	Small trucks	Medium trucks	Large trucks	Helicopters	Information request
DICONSA	3	20	3	0	2015000010014
DIF	5	0	4	0	1236000022014
IMSS	94	0	0	1	0064101319514
PC	8	10	0	1	00430914
SMEXICO	3	0	0	0	0001200186114

SVERACRUZ	0	0	0	0	00431014
SEDENA	15	45	2	0	0000700097614
SEGOB	3	0	0	0	0000400264914
SEMAR	43	0	0	0	0001300043514

The weight capacity of trucks was determined according to the minimum capacity of the truck included in each class, which were 2.5 tons for small trucks, 6.5 tons for medium trucks and 15 tons for large trucks. Helicopter capacity was set according to manufacturer specifications (http://www.russianhelicopters.aero/en/helicopters/civil/mi-817/features.html).

For this research distribution cost was associated to the consumption of fuel. SEDENA provided prospective costs as well as the calculation of cost per km for small, medium and large trucks (SEDENA, 2014a, SEDENA, 2014f). For helicopters, a range of 610 km and two fuel tanks with a combined capacity of 1870 litres of jet fuel (http://www.airforceworld.com/heli/eng/mi8.htm) were considered in the analysis. Using the consumptions for each one of the cases in combination with fuel prices provided by PEMEX (http://ri.pemex.com/files/dcpe/petro/epublico_esp.pdf), the price per mile was determined. The overall features of each one of the vehicles can be seen on Table 6.4.

Table 6.4. Characteristics of the vehicles considered for Veracruz

Vehicle	**Capacity**	**Fuel consumption (l/miles)**	**Fuel consumption ($/mile)**
Small	2500	0.357632	4.220058
Medium	6500	0.459813	5.591321
Large	15000	0.643738	7.827849
Helicopter	4000	4.933563	57.03199

Distance matrices

D*istance is crucial to* estimate shipment costs and coverage. The distances between demand areas and shelters, as well as the distance between DCs and shelters were obtained. TransCAD® *was used using the layers of facilities, centroids and the road network to obtain road and Euclidian distances.* Road distances obtained were compared with results from Google Maps®. Having the distances and the cost of transportation per mile, the shipment costs were estimated as the multiplication of two times the distance between facilities times the cost per mile of the transportation mode. The distance incurred was considering the trip to the facility and the trip back.

To ensure people are not allocated to a facility too far away from their household, the decision-maker can introduce a sensible threshold for the maximum evacuation distance. If the distance between demand areas and the facility is lower than the threshold, a value of 1 is allocated; otherwise a value of 0 is included in the matrix. For the case of Veracruz, a distance of 10 miles was considered to obtain the coverage matrix.

Personnel

The allocation of personnel is a major decision factor in this work given the services provided by governmental authorities. Each one of the agencies was questioned about the number of people used, number of people available, the allocation to different activities and the requirements per activity according to expert advice.

Required DC personnel are the number of people required for the facility to operate properly. To avoid infeasibility, a factor was added to allow partial opening of the facility. Using the information from PCV (2014b) and assuming 2 meters of storage height, the result was that each employee could manage 60 m^3 of space in the DC.

For shelter attention and healthcare, there were different responses about personal required. PCV (2014e), PCV (2014g) and SEDENA (2014g) provided useful parameters, but it was PCV (2014a) who provided the most comprehensive information. Considering the consistency of this reply with other responses, the threshold of 20 employees for 300 people was considered in the analysis for shelter care, whereas 2 people per 300 people was used for healthcare. Referring to the latter, every response stated the need for personnel with different abilities for healthcare such as doctor, nurse, dentist and assistants. For the purposes of this work healthcare was considered based on term of teams. For Veracruz that meant a team of 2 employees to serve 300 people.

For relief distribution, depending on the transportation mode, the crew required is different. Considering the different inputs from SEDESOL (2014), SSPPC (2014g), SEDENA (2014j), DICONSA (2014c) and PCV (2014d), the number of people considered can be found on Table 6.5.

Table 6.5. Number of personnel required per transportation mode

Vehicle	Number of employees
Small truck	5
Medium truck	6
Large truck	11
Boat	3
Helicopter	4

The nine agencies were enquired about the number of people used for shelter care, healthcare, DC management and distribution as well. Using information from PCV (2014h), DIF (2014a), SEDENA (2014o), SEDENA (2014q), DICONSA (2014e), DICONSA (2014c), PCV (2014d), PCV (2014e), SSV (2014b), IMSS (2014b) and SEGOB (2014g), Table 6.6 displays the information of available employees per organisation and per activity. It is important to mention that medical personnel was considered specialized and independent, whereas personnel for DC management, shelter care and distribution was considered as interchangeable except when specifically stated otherwise.

Table 6.6 Personnel available per organisation per activity

	DICONSA	DIF	IMSS	PC	SMEXICO	SVERACRUZ	SEDENA	SEGOB	SEMAR
DC management	72	60	123	36	0	0	359	8	141
Shelter care	0	60	123	36	0	0	359	8	141
Healthcare	0	0	228	0	0	970	0	0	0
Distribution	72	60	123	36	0	0	359	8	141

Wages represent one of the terms controlling the number of agencies involved. The value of the wages includes payment for all the personnel available of an agency, and that cost is only incurred if the agency is used. The wages were obtained through a consultation on the transparency information system about salaries from every organisation (http://portaltransparencia.gob.mx/buscador/search/search.do?method=begin), pages from regional agencies for State organisations and the salary tables provided by SHCP at http://www.shcp.gob.mx/lashcp/marcojuridico/marcojuridicoglobal/otros/350_aampspdeapf.pdf. Wages for healthcare were obtained from http://salud.edomexico.gob.mx/html/transparencia/informacion/tabulador/Tabulador_Sueldos.pdf, and the cost per team of one doctor and one nurse was considered as the sum of the wages of both. The wage was estimated for the unit of time of first responders of 4 days out of 30 days of work, i.e. 13.33% of the total wage. That was multiplied times the number of people available at each organisation. Table 6.7 shows the wages paid per organisation for the scenarios in Veracruz.

Table 6.7. Wages per organisation for a flood in Veracruz

Agency	Type of personnel	Number of employees	Wage (MXN)	Total wage (MXN)
DICONSA	Operative	72	1,154.251	83,106.05
	Healthcare	0	-	
DIF	Operative	60	1,768.933	106,136
	Healthcare	0	-	
IMSS	Operative	123	1,209.237	677,087.4
	Healthcare	114	4,634.66	
PC	Operative	36	2,236.352	80,508.67
	Healthcare	0	-	
SMEXICO	Operative	0	-	0
	Healthcare	0	3,473.867	
SVERACRUZ	Operative	0	-	2,714,319
	Healthcare	485	5,596.533	
SEDENA	Operative	359	1,283.467	460,764.5
	Healthcare	0	-	
SEGOB	Operative	8	783.48	6,267.808
	Healthcare	0	-	
SEMAR	Operative	141	1,283.467	180,968.8
	Healthcare	0	-	

6.1.3.2 Application of the preparedness model to the three scenarios at Veracruz

The preparedness model was coded into GAMS® choosing Cplex as solver for mixed-integer programming using a desktop with an Intel core i7 CPU and 16 GB of RAM memory, combination used throughout all of this research. To obtain the set of efficient points for the bi-objective problems, two techniques were applied: the weighted-sum method and the ε-constraint method.

For the case of Veracruz, each method was run for 200 iterations with a time limit of 450 seconds. As none of the methods ensures to obtain only efficient points, the 400 points of each scenario were refined to get a total of 38, 67 and 102 non-dominated points for 0.5, 1.5 and 2.5 meters of flood depth respectively. The Pareto frontier of the three cases is displayed on Figure 6.11.

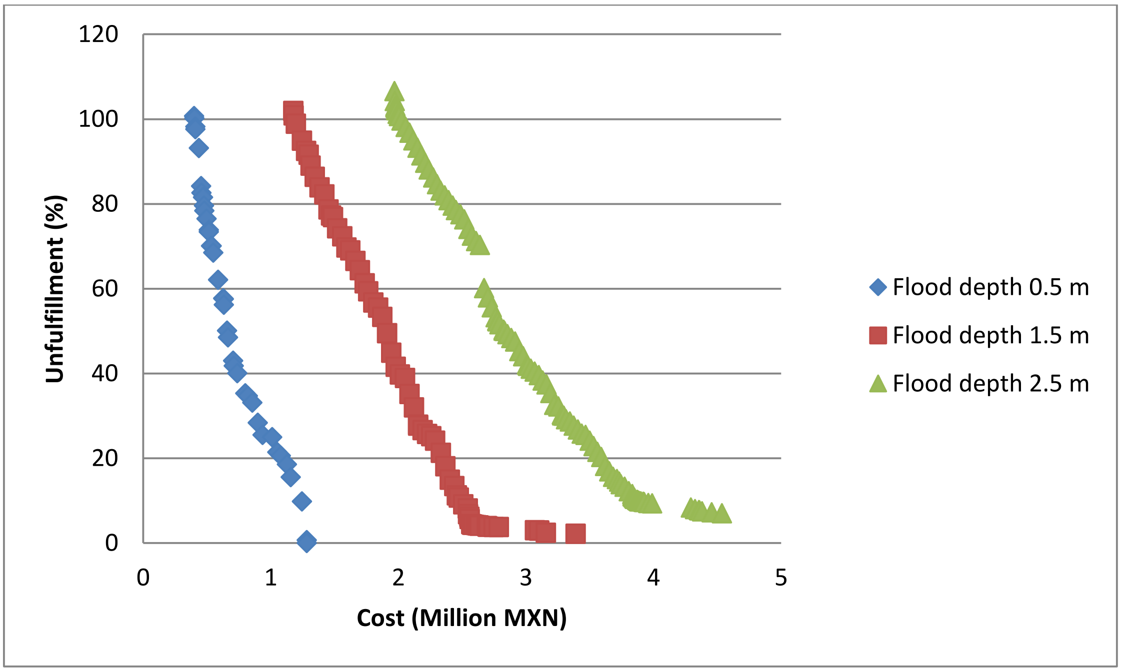

Figure 6.11. Pareto frontier of the three scenarios for preparedness in Veracruz

As expected, the greatest the demand the more expensive the operation becomes. Each one of the points presented includes a policy for preparedness and the features of each one of the points are included into Tables G.1, G.2 and G.3 on Appendix G. A summary of the overall results are shown on Table 6.8.

Table 6.8. Overview of the results of the efficient points of the three preparedness scenarios in Veracruz

Flood	Cost		Maximum agencies	Maximum fill rate (%)				Shelters		Max DCs
	Min	Max		Food	Med	NVH	NVS	Min	Max	
0.5 m	399,930.59	1,283,376.10	5	100	100	100	100	3	13	4
1.5 m	1,176,422.01	3,389,298.5	7	100	81.71	100	100	5	22	4
2.5 m	1,968,615.49	4,536,837.34	6	100	48.84	100	100	12	31	4

Regarding the number of agencies, the reason the second scenario includes one policy with seven agencies whereas the third scenario has a maximum of six agencies is due to the type of agencies activated. The activation of SEDENA, one of the largest agencies, in the third scenario involves more people that the inclusion of SEMAR and PC combined in the only solution with seven agencies on the second scenario.

6.1.3.3 Discussion of the results of the preparedness scenarios at Veracruz

The solution time of 450 seconds per iteration was satisfactory, depicting the Pareto frontier for the three situations. Both performance measures are displaying the expected conflict between them with a cost-effective and a serviced-oriented solutions.

According to the results, there was no need to involve more than 7 out of the 9 agencies that actually helped on the disaster. The reason is that the model is considering the overall resources available and choosing the best possible combination, whereas in the real case agencies were activated to have all of the possible help available. Therefore the model is showing a possibility for improvement introducing the optimal use of resources.

The distribution of medicine kits and the provision of shelter attention were the selection for low-cost solutions, incorporating food distribution and finally healthcare for more service-oriented policies. The reason is associated to the cost per person per product and the amount of personnel available. A food pantry can provide relief at $44.02 per person whereas the medicine kit can bring help with MXN $25.66 per victim. Similarly, there is higher availability of operative personnel than healthcare personnel, and the latter requires activation of specialised organisations.

The Min-Max approach seeking fairness worked as expected, although there is a lesser effect on low-cost solutions. Conversely, for high levels of fill rate the gap between the minimum and maximum values is minimised, yielding consistency across shelters. That outcome is in line with the assumption that service-oriented decision-makers are more interested on fairness than cost-driven people.

As can be seen on Table 6.8, the model is able to provide a solution with fewer shelters than the ones used in the actual flood, but several of the solutions are delivering higher numbers. The reason is linked to two factors: the coverage constraint enforcing shelters to be closer to ten miles, and the service availability from the opened DCs. The model is deciding to have more small shelters to cover the whole area than fewer big shelters. Building upon that, the occupancy of shelters in average shows appropriate use of the facilities, with most of the solutions over 80% of use.

The results of stock prepositioning and expected relief distribution show that all the demand for food pantries and services can be fulfilled on the three scenarios, whereas the limitation on medicines affects the fill rate under different circumstances. As medicines are valuable perishable items it is understandable to have very low inventories prepositioned, however the result from the analysis shows the need to look further into that decision.

According to the model, the evacuation for the flood of 1.5 meters would involve travelling between 3.36 miles and 4.47 miles per person, which can be a challenge for foot evacuation.

To sum up, the result suggests the model is delivering rational solutions in line with the expectations, assessing the management of different situations with current resources.

6.1.3.4 Solutions selected for the three preparedness cases in Veracruz

The response model is considering the possibility to use a decision tool for preparedness and deploy initial resources. Therefore, the number and location of facilities along with the number and allocation of resources per agency deployed on the initial stage can be introduced from the results of the preparedness model to give continuity to the policy implemented initially.

For the selection the author of this dissertation operated as decision-maker with a high focus on fill rate, the number of facilities, use of resources, and lastly cost. After checking the solutions included on Appendix G, and revising the options proposed to the supervisors of this work, the policies with the metrics displayed on Table 6.9 were deemed appropriate.

Table 6.9. Metrics of the solutions chosen for the three cases in Veracruz

Depth	ID	Cost (MXN)	Org	Fill Rate (%)				Facilities		Use Human Resources (%)		Vehicles	
				Food	Med	NVH	NVS	Shel.	DCs	Operative	Healthcare	Total	Trips
0.5 m	38	1,283,376	3	100	100	100	100	7	1	83.5	9.7	3	7
1.5 m	57	2,637,728	6	100	81.7	100	96.9	6	2	43	94.2	16	7
2.5 m	94	3,959,033	6	100	48.8	100	95.9	19	4	33.3	95.7	15	29

6.1.4 Response optimisation model applied on Veracruz

The bi-criteria optimisation model provides support for the allocation of resources, inventory management and distribution decisions aligned with similar goals to the preparedness model, including several periods for the response activity.

6.1.4.1 Data collection for the response scenarios on Veracruz

To perform the analysis, information about type and storage capacity of the demand areas, the list of commodities available for response, personnel availability and supply capacity per period per agency, minimum fill rate per product every three periods, demand of people and items, and initial allocation of resources was required.

The initial allocation of resources along with the number and location of facilities were obtained from the results selected from the preparedness model for each scenario. The rest of the information was obtained with formal requests to the transparency system for 9 governmental organisations. As a note, for the response stage DICONSA was renamed as FONDEN. The reason is because even though DICONSA is still the main provider of food, FONDEN handles a wider range of products and the money comes directly from this fund. Also noteworthy is that international aid was not required for this event (SRE, 2014), information about the performance of Mexican Red Cross (REDCROSS) was undisclosed, and the enquiry for information from NGOs and other organisations was unsuccessful.

As no information was available about the number of employees and vehicles available per period, the same number of personnel and vehicles included on the preparedness model was considered available for every period.

Historical data along with information about the actual event can be used to estimate the interval for distribution, or the model can be used period-to-period to update decisions at every stage. This work is choosing to support the former more than the latter, given the importance of considering the evolution of events through time. Defining a period, it is an interval of time between one decision and the next, and it should be long enough to perform the activities planned. For example, in Mexico some of the kits are design to last four days and it can be considered a period until the next delivery.

Taking out that initial response provided by the preparedness model, six periods of four days were used as input to cover the 26-day disaster (SSV, 2014a). Even though the number of periods is dependent on the scale of the event, the comparison between scenarios was considered relevant, thereby the decision to include the same number of periods for the three scenarios. Also, only one day was considered for distribution, considering the rest of time for procurement and preparation of the items.

Demand areas

As the focus of this work is around sheltered people, no other demand areas were included. The storage capacity of shelters was obtained using the assumption of 0.5 square meters available for storage per person at each facility, delivering the results shown on table D.1. The assumption is based on the space available per person (Sphere_Project, 2011) and one meter of storage height.

The main challenge for the demand areas is to forecast shelter demand over all periods. Even though information about the maximum number of people sheltered is available, people tend to arrive/leave on different periods. Given the need to input information as close as reality as possible, all the agencies were surveyed about the number of people sheltered through time to use the historical data to build a forecast. Only SSV (2014a) kept records of the number of people sheltered per day, representing little less than 30% of the total of people sheltered. From that data, the relative percentage in relation to the maximum number of people sheltered was obtained for each day and it was projected to the total number of evacuees. The results can be seen on Table H.1 on Appendix H.

Relief items

Food pantries and medicine kits were considered along with other living items required. The items that can be charged to FONDEN are properly regulated and included in the Appendix IV of SEGOB (2012), involving 42 different products. These products were checked to identify the ones to include in the response model, and the details can be seen on Table F.5 on Appendix F. A total of 10 items including food pantries, cleaning kits, personal kits, feminine hygiene towels, and six types of diapers are considered for the response model. Aggregating items depending on the diversity of people on each shelter that are replenished continuously such as diapers and feminine hygiene towels, one kit for 100 people according to the distribution of the population in Mexico was used. The ‘hygiene kit’ contains 19 feminine hygiene towels and 110 diapers, as explained on Appendix F. The items incorporated for the response model with their features are shown on Table 6.10.

Table 6.10. Characteristics of the relief products included for the response model

Name	People served	Replenishment	Weight (kg)	Volume (m^3)	Price (MXN)	Source
Food pantry	4	Every 4 days	7.47	0.024	176.06	FONDEN Appendix IV
Medicine kit	100	Every month	18.2	0.038	2,566.37	Health ministry and commercial sites
Cleaning kit	4	Every month	2.5	0.0625	135.00	FONDEN Appendix IV
Personal kit	4	Every 4 days	0.7	0.0625	73.00	FONDEN Appendix IV
Hygiene kit	100	Every 4 days	6.45	0.774	314.5	FONDEN Appendix IV and commercial sites

Having the complete set of products, the decision maker has the opportunity to establish a minimum threshold of fill rate every three periods to account for deprivation and seek equity. For Veracruz, 80% fill rate every three periods was requested for food and medicines, whereas only 50% for cleaning and personal kits along with 20% for the hygiene kit. Food and medicines were considered to have priority over other items thereby values of ‘3’ were incorporated for these items and values of ‘1’ for the rest. Using the number of people served per item showed on Table 6.10 and the demand established on Table H.1 on Appendix H, product demand was determined and included rounding-up decimal values. Usually initial demand is not the maximum demand. The difference between items shipped in the immediate response and products actually consumed is used to determine initial inventory levels. As medicines are products that last for a month, for each scenario the demand for medicines was reduced according to the amount of kits sent by the preparedness model initially.

The supply capacity provided by DICONSA (2014c) was set at 40,000 food pantries every two periods. For medicine kits, IMSS (2014a) considered 22 kits per month, translated into a mean of 6 kits every two periods. SS (2014g) declared a supply capacity of 80 kits 100 people, meaning 20 kits every two periods. As no information was provided about the rest of the items, the public information about the items sent available at FONDEN (2010) was used to determine the capacity per period.

6.1.4.2 Application of the response model to three cases on Veracruz

The weighed-sum method and the ε-constraint method were applied for 150 iterations each, with a time limit of 600 seconds per iteration. From the 300 iterations performed per scenario, a total of 100, 142 and 160 non-dominated points were obtained for the situations with a flood depth of 0.5 meters, 1.5 meters and 2.5 meters respectively; all of which are shown on the Pareto frontiers displayed on Figure 6.12.

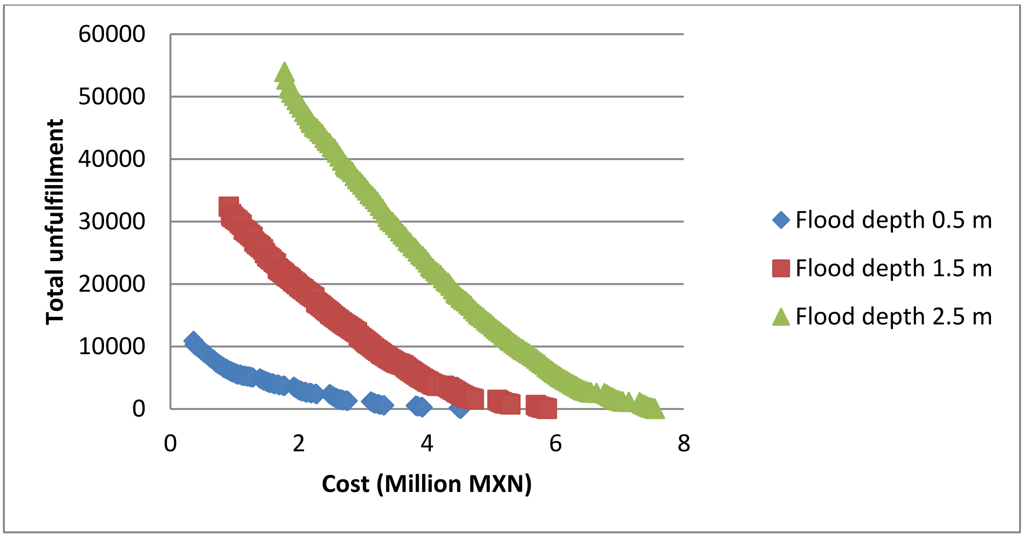

Figure 6.12. Pareto frontier of the three scenarios for response in Veracruz

Table 6.11 shows an overview of the metrics for each one of the scenarios analysed. It is noticeable that authorities count with enough capacity to handle all of the scenarios presented. Also, the number of agencies actually needed to manage all of the situations is in fact lower than the number of organisations involved in the disaster situation. The complete set of results can be perused on Appendix G.

Table 6.11. Performance measures of the results obtained for response for the three scenarios in Veracruz

Flood depth	**Cost (MXN)**		**Agencies per period**		**Maximum Fill Rate (%)**						
					Food	Med	CKIT	PKIT	HKIT	NVH	NVS
	Min	*Max*	*Min*	*Max*							
0.5 meters	362,262.93	4,522,990.17	2	5	100	100	100	100	100	100	100
1.5 meters	910,664.66	5,864,065.23	2	6	100	100	100	100	100	100	100
2.5 meters	1,774,800.12	7,542,851.95	3	6	100	100	100	100	100	100	100

As intuitively expected, response activities are more expensive than preparedness activities. However, the difference not being that large can be attributed to the short number of periods for response and the cost of facility set-up in the preparedness stage. The fact that the lower bound in cost for the second and third scenario is lower than the equivalent for the preparedness model is due to the assumptions underpinning each model. The preparedness model is bounded to provide shelter to all of the people identified in demand areas, whereas the response model is only constrained with providing food for a certain percentage of people every three periods.

6.1.4.3 Discussion of the results of the three response scenarios at Veracruz

For the response scenarios presented in Veracruz the time of 600 seconds per iteration yielded very good results, with at least one hundred efficient solutions for each situation. From the results displayed on Tables G.4, G.5 and G.6 it is noticeable the conflict between both performance measures and also the range of variation from one solution to the next.

Elaborating on the multi-organisational perspective, according to the results authorities have more than enough resources to provide support for disaster victims in the area, even decreasing the number of actors involved. That result is consistent with the results from the preparedness stage, suggesting an excessive deployment of resources. The model picked the most appropriated agencies for each one of the periods, increasing/decreasing the number of actors involved according to the characteristics of the situation.

Ranging from low-cost solutions to service-oriented policies, the model is increasing initially relief distribution, then shelter care and finally healthcare. The reason is due to the constraint about a minimum satisfaction threshold implemented to avoid the cumulative unfulfillment of relief at any shelter. For services, healthcare teams are used on more service-oriented solutions because these are scarcer and are only available on some specialised agencies.

An aspect to treat carefully is inventory. For the scenarios performed on this case the model is pushing the inventory levels towards shelters, with very low inventory on DCs. As a way to save money, the model is sending several items at once on early stages to reduce the number of trips and personnel required for DC operation. This behaviour can create challenges for authorities on-site and it should be carefully analysed.

The overall outcome of the response model in this case is yielding satisfactory results in terms of the goals presented at the design stage.

6.1.4.4 Solutions selected for the three response cases in Veracruz

For the selection of solutions, the decision-maker operated with a strong focus on fill rate but looking for good value. Analysing the Pareto frontier of every scenario and looking at the solutions presented on Appendix G, the efficient points summarised on Table 6.12 were considered as the most appropriate ones.

Table 6.12. Metrics of the solutions chosen for the three response scenarios in Veracruz

Sol	**Cost (MXN)**	**Maximum agencies per period**	**Fill Rate (%)**							**Maximum Employees per period**		**Maximum number of Vehicles per period**	
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health	Total	Trips
1-88	3,182,018	3	100	100	100	100	100	89.6	92.5	171	10	11	7
2-114	4,259,707	5	100	100	100	100	100	75.1	100	348	17	7	15
3-134	6,368,063	6	100	100	50.5	99.9	100	89.6	98.4	302	33	9	19

It is noticeable that the fill rate for healthcare is not ideal on the three cases, but that is because the activation of another agency to improve those values represents a significant increase in cost. Overall the first two solutions chosen are not even reaching 75% of the highest cost, whereas in the worst case the solution is below 85% of the maximum cost.

6.2 Acapulco, Guerrero

The city of Acapulco is located in the Pacific coast of the country on longitude 99° 52’ 572 and latitude 16°51’49” with an altitude of 30 meters (Anzaldo and Prado, 2007). The variation in altitude in the municipality is quite high, ranging from 0 to 2000 meters above sea level (INEGI, 2009a). This is due to its location next to the sea but surrounded on the other side by mountains, as shown by Figure 6.13.

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Source: INEGI (2009a)

Figure 6.13. Study region and topography of Acapulco, Guerrero

In terms of demography, according to INEGI (2010b) there were 789,971 people living in the municipality on 2010, from which 692,235 inhabited the city (INEGI, 2010c). The focus of the city on tourism is displayed by the 4,890,456 tourists visiting the region just in 2010 (INEGI, 2010a), to make it one of the most important touristic ports in the country (INEGI, 2008).

6.2.1 Conditions of the flood of 2013

Hurricane Ingrid affected the Caribbean region on mid-September of 2013, closing down to less than 100 km from to the city of Veracruz, on the gulf of Mexico (Beven, 2014). Around the same time Hurricane Manuel closed down on the Pacific coast (Pasch and Zelinsky, 2014). The latter caused 123 deaths in the country along with flooding and landslides (Pasch and Zelinsky, 2014), because of severe rainfall as shown by Figure 6.14. These conditions resulted in a flood of around 1.5 meters of depth (EOS, 2013, El_Universal, 2013).

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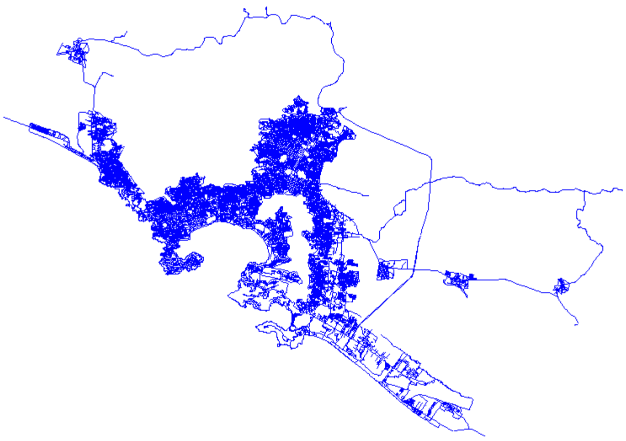
Source: Pasch and Zelinsky (2014)

Figure 6.14. Total rainfall in Mexico from 12th-20th of September 2013

6.2.2 Application of the GIS procedure on Acapulco

6.2.2.1 Layers used for the case of Acapulco

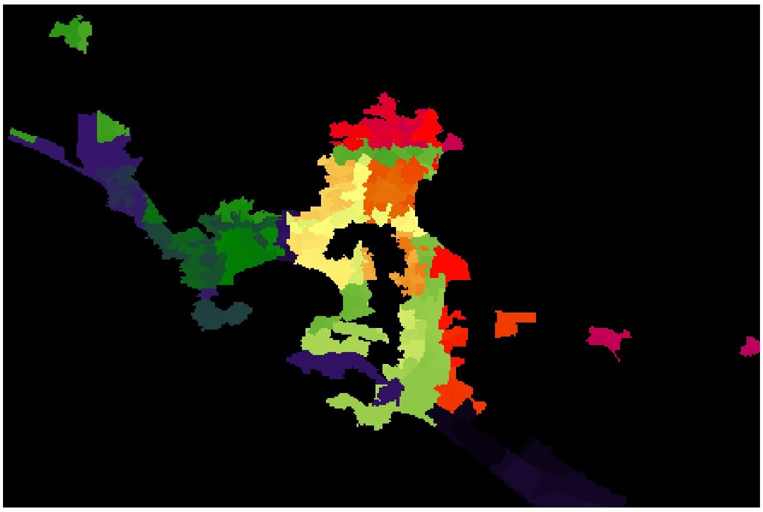
The layers required for the use of the cartographic model were obtained from authorities. The road network shown on Figure 6.15 was obtained from INEGI (2010c) on *shapefile* format.



Source: Compiled by author with information from INEGI (2010c)

Figure 6.15. Road network of the city of Acapulco

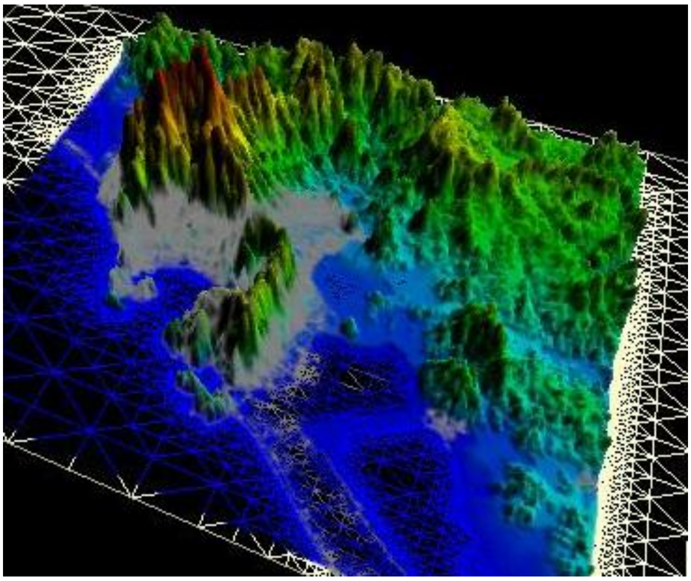
Similarly, the demand areas displayed on Figure 6.16 were obtained from *INEGI (2010c)*. The 478 units in the map are AGEBs, containing information about the number of people living in the area along with the identification number of the unit.



Source: Compiled by author with information from INEGI (2010c)

Figure 6.16. AGEBs of the city of Acapulco

The DEM was selected from a layer obtained from INEGI (2015) and another from USGS (2010), performing a series of trials to compare them both. The USGS image is shown on Figure 6.17. It did not show the inconsistencies identified in the image from INEGI around the body of water present on the southeast of the region, on top of exhibiting more precision.



Source: Compiled by author with information from USGS (2010)

Figure 6.17. Digital elevation model of Acapulco city

Regarding available shelters, the shelter catalogue with 103 facilities released by SSPPC (2013) was used. Each individual facility can be checked on Table D.3 on Appendix D. Similarly, 14 available DCs were identified for this case study as shown on Table D.4 on Appendix D, which were obtained from DIFG (2014f), DIFG (2014a), SSPPC (2014b), SSPPC (2014c), SSPPC (2014h), (SEDENA, 2014t), (SEDENA, 2014i) and DICONSA (2014c), supplemented with six facilities found according to the guidelines of SEDENA (2010). The facilities were located to create a layer for shelters and another for DCs. The combination of both layers can be observed on Figure 6.18, being shelters the medium-size purple dots and the DCs small red dots.

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Figure 6.18. Available facilities for Acapulco city

6.2.2.2 GIS procedure for the case of Acapulco

According to Anzaldo and Prado (2007), the city is in average 30 meters over sea level. However, given the resolution of the image and also the importance of the baseline for the analysis a manual procedure was applied. According to the tests, a base value of 8 meters was determined. Considering the height of 1.5 meters of flood depth of the real case, three scenarios were selected: a flood depth of 0.5 meters, 1.5 meters and 2.5 meters. Applying the cartographic model showed on Section 5.1.3, the results are displayed on Figure 6.19.

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Figure 6.19. Flood of 0.5 meters, 1.5 meters and 2.5 meters at Acapulco

6.2.2.3 Results of the GIS procedure applied to Acapulco

Figure 6.20 shows the candidate facilities where the small dots represent candidate shelters and the medium ones represent candidate DCs.

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Figure 6.20. Surviving facilities for floods of 0.5 meters, 1.5 meters and 2.5 meters at Acapulco

The analysis yielded a total of101 shelters available for the scenario of 0.5 meters, and 99 shelters remaining for the floods of 1.5 and 2.5 meters, as shown on Table E.4 on Appendix E. On the other hand, Table E.5 on Appendix E shows that 12 candidate DCs survived the conditions for the floods of 0.5 meters and 1.5 meters, whereas the situation with a height of water of 2.5 meters delivered 10 candidate DCs.

Focusing on the damage caused by the floods to the demand areas, the flood of 0.5 meters affected nearly 17.6% of the total area, whereas the flood of 1.5 meters and 2.5 meters damaged around 19.9% and 22% of the region, respectively. In that sense, Table 6.13 shows the number of AGEBs affected per level of damage. Around 5.2%, 5.9% and 6.9% of the AGEBs for each one of the scenarios were completely covered by water. For further enquiry, Table E.6 shows the damage to each individual AGEB.

Table 6.13. Number of AGEBs affected per percentage of damage for the three scenarios in Acapulco

Percentage of damage	**0.5 m**	**1.5 m**	**2.5 m**	***Percentage of damage***	**0.5 m**	**1.5 m**	**2.5 m**
Not affected	394	383	373	*50<x<60*	2	4	7
1<x<10	19	24	30	*60<x<70*	6	5	3
10<x<20	12	11	9	*70<x<80*	3	3	7
20<x<30	5	6	7	*80<x<90*	4	6	5

30<x<40	5	5	3	*90<x*	25	28	33
40<x<50	3	3	1				

Regarding the damage to the roads, the flood map along with the road network was used to obtain the connectivity matrix using of the Floyd-Warshall algorithm explained on Section 5.1.3.3. For each combination of facilities a value of 1 was input as long as there was at least one road available between the facilities and 0 otherwise. For the latter boat transportation was assumed to be possible.

6.2.3 Preparedness optimisation model applied in Acapulco

6.2.3.1 Data collection for the scenarios on Acapulco

A total of 83 requests were submitted to four regional agencies in charge of disaster management in the state, and 122 requests were submitted to eight National agencies. The complete list of requests can be checked on Appendix C.

From the twelve agencies identified, CENAPRED and SRE were enquired about reports and international aid. The agencies that provided operative information were: DICONSA, DIF, IMSS, Civil Civil Protection and Public Security Secretariat of Guerrero (SSPPC), SMEXICO, State Health Ministry of Guerrero (SGUERRERO), SEDENA, SEDESOL, SEGOB and SEMAR.

Relief items

Food and medicines were considered as the main elements to stock for preparedness. Prices for the items distributed after the flood in Acapulco were not available given legislation limitations pointed out by DICONSA (2013). Because of that, and the absence of evidence about the products delivered on Acapulco after the changes on the basic food pantry in 2012, the products included on Table 6.2 were used for the flood in Acapulco with the same prices.

Product inventory

The ten operational agencies included in the case were asked about the number of products available previous to the disaster in 2013. Food pantries were reported only by DICONSA (2014a) with 2,500 products available for distribution in the area, considering no other products. In terms of medicine kits, SSG (2014a) stated possession of 1 kit for 1,000 people for first response. IMSS (2014b) declared a capacity of 1.5 kits for 1,000 people per month, whereas SS (2014g) stipulated the existence of 2 kits for 1000 people in cases of disaster.

Shelters

The location and description of the shelters considered for the case of Acapulco are included on Appendix D; whereas the identification and digitization process is included on Section

6.2.2.1. Capacity was determined according to three sources: the capacity declared by authorities, number of people actually sheltered, and the space available. For cases where available capacity and used capacity was different, the capacity of the facility was used, given that authorities could have allowed overcrowding.

Regarding facility set-up cost, information from DIF (2014b) was used to obtain a price of MXN $2.42/m^2 and multiplied times the indoor space of each facility. The expenditure on living items provided in shelters was added to cleaning cost in order to obtain the total preparation cost per shelter shown on Table D.2.

Demand

The number of people in the area was obtained based on information from INEGI (2000) and INEGI (2010b) by applying the method provided by INEGI (2014) to estimate the growth rate of 0.8968% per year. That value was used to extrapolate the population in Acapulco from 2010 to 2013 in each one of the AGEBs. Having the population at the time, the actual demand at shelters served by authorities in the flood of 2013 was obtained from SSG (2014a), SSPPC (2014a), SEDENA (2014c) and IMSS (2014b); cross-referencing the information using a 'worst case approach' and yielding a total de 13,062 people. For the case of the other two scenarios, a lineal relationship between the flood depth and the number of people sheltered was assumed. The results were a total of 4,357 and 21,773 people for the scenarios of 0.5 meters and 2.5 meters of water respectively. (IMSS, 2014b). To identify the origin of the demand, the percentage of people using shelters was multiplied times the number of people affected per demand area.

Distribution centres

A combination between the facilities identified by authorities and facilities available in the area according to the guidelines of SEDENA (2010) was used for the three scenarios. The capacities were obtained from SSPPC (2014b), SSPPC (2014h), SEDENA (2014t) and the procedure described on Section 6.1.3.1. Cleaning cost was determined by multiplying the $\frac{cost}{m^2}$ times the indoors area inside the premises of the facility. D.4 shows the complete features of the DCs considered for the case of Acapulco.

Transportation modes

Each agency involved was enquired about the number, type and capacity of vehicles used during the disaster. Table 6.14 displays the number of vehicles available in Acapulco for disaster management according to information from seven agencies.

Table 6.14. Vehicles available in Acapulco

Agency	Small	Medium	Large	Boats	Information Request
DICONSA	0	5	17	0	2015000001214 and 2015000003414
SGUERRERO	14	0	0	0	00026514
SEDENA	38	110	34	0	0000700002814 and 0000700031514
SEDESOL	8	0	0	0	00026714 and 00026914
SEGOB	3	0	1	0	0000400264914
SEMAR	41	0	0	0	0001300056914
SSPPC	4	0	0	4	00000914 and 00142214

In terms of capacity, the same information presented on Section 6.1.3.1 and displayed on Table 6.4 was used. As boats are introduced for this case, the capacity was found on commercial sites of boats with 55 HP engines (http://www.puntonautico.com.ar/lanchas-quicksilver-marinesur/lancha-quicksilver-marinesur-1500/). Assuming 80 kg per person a capacity of 320 kg was obtained. Fuel consumption was obtained for a 55 HP engine using Diesel at a constant speed of 25 Km/h, using information from Becker (2000). The overall features of each one of the vehicles considered for the case can be seen on Table 6.15.

Table 6.15. Characteristics of the vehicles considered for Acapulco

Vehicle	Capacity	Fuel consumption (l/miles)	Fuel consumption ($/mile)
Small	2500	0.357632	4.220058
Medium	6500	0.459813	5.591321
Large	15000	0.643738	7.827849
Boats	3000	0.744581	9.05411

Distance matrices

On TransCAD® *the layers of road network, centroids and facilities were used to determine road and Euclidian distances for land and boat transportation, respectively.*

The shipment cost was estimated as the multiplication of two times the distance between facilities times the cost per mile of the transportation mode considering the prices estimated on Table 6.15 for each type of vehicle.

For coverage, a threshold of 15 miles was considered given the features of the area, assigning 1 to values below that number and 0 otherwise to create the matrix.

Personnel

The personnel required for DCs, shelter attention and distribution considered was the same as the case of the case for Veracruz explained on Section 6.1.3.1. The reason is because the limited nature of the responses and the inclusion of the opinion from different authorities. For healthcare, the consistency between the answers from SEDENA (2014g) and SSG

(2014c), teams of one doctor, a nurse, a dentist and two helpers for 90 people sheltered were included.

Every organisation reported the number of employees per activity shown on Table 6.16. Personnel for DC management, shelter care and distribution was considered as interchangeable except specifically stated otherwise.

Table 6.16. Personnel available for the case of Acapulco

Agency	DC	Shelter	Healthcare (teams)	Distribution	Information request
DICONSA	45	0	0	45	2015000001514, 2015000003314 and 2015000003614
DIF	391	391	0	391	00027214, 00027014 and 00006414
IMSS	0	0	14	0	0064100439314 and 0064100439514
SGUERRERO	716	716	220	716	00026214 and 00107514
SMEXICO	127	127	6	127	0001200006514
SEDENA	418	418	0	418	0000700002914 and 0000700031414
SEDESOL	80	0	0	80	00108314, 00026614 and 00026814
SEGOB	23	23	0	23	0000400265014, 0000400264914
SEMAR	1103	1103	0	1103	0001300043414
SSPPC	20	20	2	20	00000814, 00096214 and 00142214

Information from the transparency information system and salary tables provided by SHCP were used to determine the income for operative personnel, whereas the earnings of healthcare teams were obtained through the salary table available at: http://salud.edomexico.gob.mx/html/transparencia/informacion/tabulador/Tabulador_Sueldos.pdf. Table 6.17 displays the wages considered for the application of the model, considering 4 out of 30 days of work. Healthcare wages include the wages of every member of the team.

Table 6.17. Wages per organisation for a flood in Acapulco

Agency	Type of personnel	Number of employees	Wage (MXN)	Total wage (MXN)
DICONSA	Operative	45	1,154.251	51,941.28
	Healthcare	0	-	
DIF	Operative	391	906.71	354,522.8
	Healthcare	0	-	
IMSS	Operative	0	-	150,824.1
	Healthcare	14	10,773.15	
SSPPC	Operative	20	1,321.04	39,631.32
	Healthcare	2	6,605.22	
SMEXICO	Operative	127	12,26.67	223,824.3
	Healthcare	6	11,339.6	
SGUERRERO	Operative	716	1,385.6	3,486,802
	Healthcare	220	11,339.6	
SEDENA	Operative	418	1,283.467	536,489.1
	Healthcare	0	-	
SEDESOL	Operative	80	1,057.247	84,579.73
	Healthcare	0	-	

SEGOB	Operative	23	783.48	18,019.95
	Healthcare	0	-	
SEMAR	Operative	1103	1,283.467	1,415,664
	Healthcare	0	-	

6.2.3.2 Application of the preparedness model to the scenarios in Acapulco

The weighted-sum method and the ε-constraint method were applied for 200 iterations per method per scenario, with a time limit of 450 seconds. After filtering only non-dominated solutions, Figure 6.21 depicts 39 efficient points for the first scenario, 62 solutions for the emulation of the real case and 86 non-dominated points for the case of a flood of 2.5 meters.

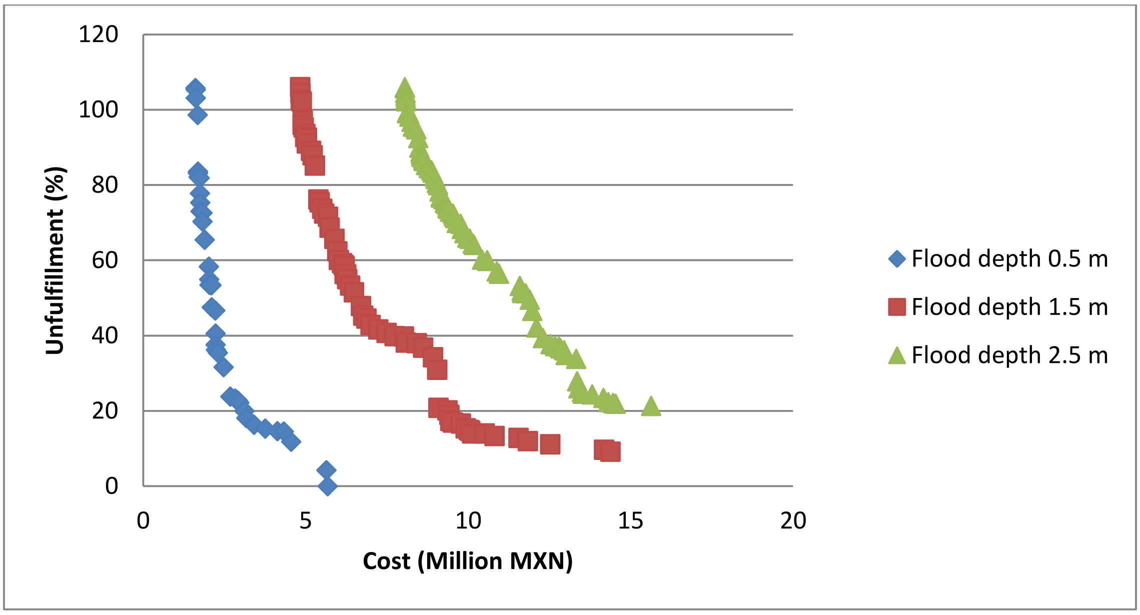

Figure 6.21. Pareto frontier of the three scenarios for preparedness in Acapulco

The features of each one of the solutions can be checked on Appendix G. Table 6.18 contains an overview of the results showing that only a flood of 0.5 meters can be managed with the current resources to attain 100% of demand satisfaction.

Table 6.18. Overview of the results of the efficient points of the three scenarios in Acapulco

Flood	**Cost**		**Maximum**	**Maximum Fill Rate (%)**				**Shelters**		**Max**
	Min	**Max**	**agencies**	**Food**	**Med**	**NVH**	**NVS**	**Min**	**Max**	**DCs**
0.5 m	1,609,918.68	5,676,227.86	6	100	100	100	100	10	29	8
1.5 m	4,830,802	14,379,448	9	76.56	34.45	100	100	31	79	11
2.5 m	8,057,277.04	15,634,537.56	8	45.93	20.29	96.4	99.98	63	92	7

It is possible to provide healthcare and shelter care to nearly every victim affected by the disaster on the three cases, showing that there are enough human resources in the area. Conversely, there are not enough relief items in the region for scenarios over 0.5 meters of flood depth, which is relevant thinking that the actual flood corresponds to the characteristics of the second scenario.

It seems the second scenario could involve more agencies than the third scenario for a couple of solutions. Checking the solutions, SEMAR, as one of the largest agencies, is never activated on the second scenario, whereas it is activated on the third. Instead, SEGOB, a fairly small agency is activated for the second scenario but not in the third. It seems that to obtain the highest fill rate on the third scenario the model opens SEMAR and closes smaller agencies render unnecessary.

6.2.3.3 Discussion of the results of the three preparedness scenarios in Acapulco

Obtaining a good set of solutions with the time of 450 seconds, Tables G.7, G.8 and G.9 display the conflict between both performance measures delivering cost-effective and service-oriented solutions.

In none of the three scenarios it was necessary to activate all of the agencies. It can be argued that for the real case the use of ten agencies is not far from a couple of solutions activating 9 agencies, nevertheless it is fair to highlight that SEMAR, the agency that was not opened, represents nearly 38% of the total operative personnel available. Therefore, the results of the model point out to an excess of human resources used for the event.

The Min-Max approach is having the expected impact, especially for service-oriented solutions, but a new dimension for the measure of fairness is shown in the results. The lack of products to satisfy all of the demand forces the model to close the gap between shelters even further. The value of the fairness measure is more noticeable on these results given the combination of focus on fill rate and scarcity of products.

Available items prepositioned for relief distribution seem insufficient for moderate to catastrophic conditions. As a matter of fact, this conclusion was supported by measures taken by Mexican authorities *after* the flood in 2013, increasing the amount of prepositioned stock in the region from 2,500 to 10,000 food pantries (DICONSA, 2014d). It can be argued that using an analytic tool to analyse the conditions in the region prior to the situation could have served to identify this shortcoming earlier, and it could be more suitable for future analysis than just approximating the number of people served on the last experienced event.

Ranging from low-cost solutions to service-oriented solutions, the model is looking to satisfy first the need of medicines and then the requirements of food because of the relation cost/service, whereas the preference of shelter attention over healthcare is also present.

In reality, a total of 56 shelters and 6 DCs were opened by authorities. The scenario with real conditions opens fewer facilities than the actual number opened by authorities on more than 91% of the solutions, showing that the number of facilities might have been unnecessary.

Elaborating on the use of the shelters, the occupancy rate in average shows appropriate use of the facilities, with most of the solutions over 80% of use.

According to the results the evacuation would represent between 8.75 and 10.55 miles of travel per person, a factor that should be seriously considered and evaluated on Chapter 7 to discuss the complications created by this result.

Overall the outcome obtained fall within the boundaries of the expected and desirable results, with an adequate use of resources.

6.2.3.4 Solutions selected for the three preparedness cases in Acapulco

The author of this dissertation operated as decision-maker to select a solution for each scenario with a high focus on fill rate, the number of facilities, use of resources, and lastly cost. After checking the solutions included on Appendix G and the options proposed to the supervisors, the policies displayed on Table 6.19 were considered appropriate for their use.

Table 6.19. Metrics of the solutions chosen for the three cases in Acapulco

Depth	SOL	Cost (MXN)	Org	Fill Rate (%)				Facilities		Use of Human Resources (%)		Vehicles	
				Food	Med	NVH	NVS	Shel.	DCs	Operative	Healthcare	Total	Trips
0.5 m	39	5,676,228	4	100	100	100	100	10	1	45.74	36.67	5	10
1.5 m	54	10,061,802	6	76.13	33.39	99.94	99.98	42	6	99.81	82.64	19	46
2.5 m	80	13,532,231	7	45.61	20.14	96.08	99.75	77	5	99.64	100	25	76

The first scenario includes the most costly solution given the desire to obtain complete fulfilment over products and services, whereas the other solutions are below 90% of maximum cost. The use of agencies is considerably lower compared to the number of organisations available, and the policies selected are seeking a low number of facilities.

6.2.4 Response optimisation model applied on Acapulco

6.2.4.1 Data collection for the three cases on Acapulco

The initial allocation of resources along with the number and location of capacities were obtained from the results selected from the preparedness model for each scenario.

For this case, it was possible to obtain information from Red Cross, increasing the number to eleven organisations involved. There are reports stating the participation of ADRA, OCHA and Doctors without Borders, but there was no reliable and specific information to include them in the analysis. Besides, the Mexican government decided not to request international aid for the flood in Acapulco (SRE, 2014).

As no information was available about the number of employees and vehicles available per period, the same number of both included on the preparedness model was considered available for every period. For Red Cross, Table 6.20 shows the number of employees and relief items available (RED_CROSS, 2013). The salary of paramedics came from http://salud.edomexico.gob.mx/html/transparencia/informacion/tabulador/Tabulador_Sueldos.pdf, for a total wage of MXN $120,256 per period. Even though more people were available country-wide, only the number of people specifically identified in Acapulco was considered. Trailers were not considered for inter-city transportation. Finally, relief sent to Guerrero/Acapulco was transformed from tons to products using the data from Table 6.2.

Table 6.20. Contributions from Red Cross for the flood in Acapulco

	20-Sep	23-Sep	24-Sep	25-Sep	26-Sep	01-Oct	07-Oct	10-Oct
Food pantries	1874	2952	1119	1187	700	0	0	525
CKIT	1874	2952	1119	1187	0	0	0	87
PKIT	1874	2952	1119	1187	0	0	0	0
Employees	60	60	60	60	60	60	60	40
Trailers (total)	0	10	7	0	0	130	185	0

Considering the unit of 4 days per period, a total of 12 periods were included for the study to provide support for the 44 days declared by authorities (SSPPC, 2014f). The same number was used for the three scenarios in order to ease the comparison. Finally, only one day was considered for distribution allowing three days for other activities.

Demand areas

The demand areas included in the analysis were shelters without other consumption points. The storage capacity of shelters was obtained using the assumption of 0.5 square meters available for storage per person at each facility, delivering the results shown on Table D.2.

The evolution of demand over all periods was analysed using information from SSPPC (2014f), which was the only organisation with records of demand over the duration of the flood. SSPPC sheltered over 65% of the total demand, therefore the relative percentage of people sheltered was obtained for each day and it was projected to the total number of evacuees. The results can be seen on Table H.2 on Appendix H. Based on those results and the values from Table 6.10, product demand was estimated. The relief items delivered in the preparedness stage were considered for initial inventory levels and product demand.

Relief items

The products presented on Table 6.10 were included. For equity purposes, an 80% fill rate every three periods was requested for food and medicines, 50% for cleaning and personal kits and 20% for the hygiene kit for the three cases. Food and medicines were considered *top* items with priority values of ‘3’ and values of ‘1’ for the rest.

FONDEN declared the availability of 40,000 food pantries every two periods (DICONSA, 2014c). For medicine kits, IMSS (2014a) a capacity of 48 kits every two periods was obtained. Similarly, SS (2014g) declared supply capacity of 106 kits every two periods. Public information about all the items sent available at FONDEN (2013) was used to determine the capacity per period of the rest of the products.

6.2.4.2 Application of the response model to three cases on Acapulco

The weighed-sum method and the ε-constraint method were applied with loops of 150 iterations and a time limit of 600 seconds per iteration. A total of 126, 54 and 30 efficient solutions were obtained for the scenarios of 0.5, 1.5 and 2.5 meters, respectively. The Pareto frontier of the three scenarios is shown on Figure 6.22.

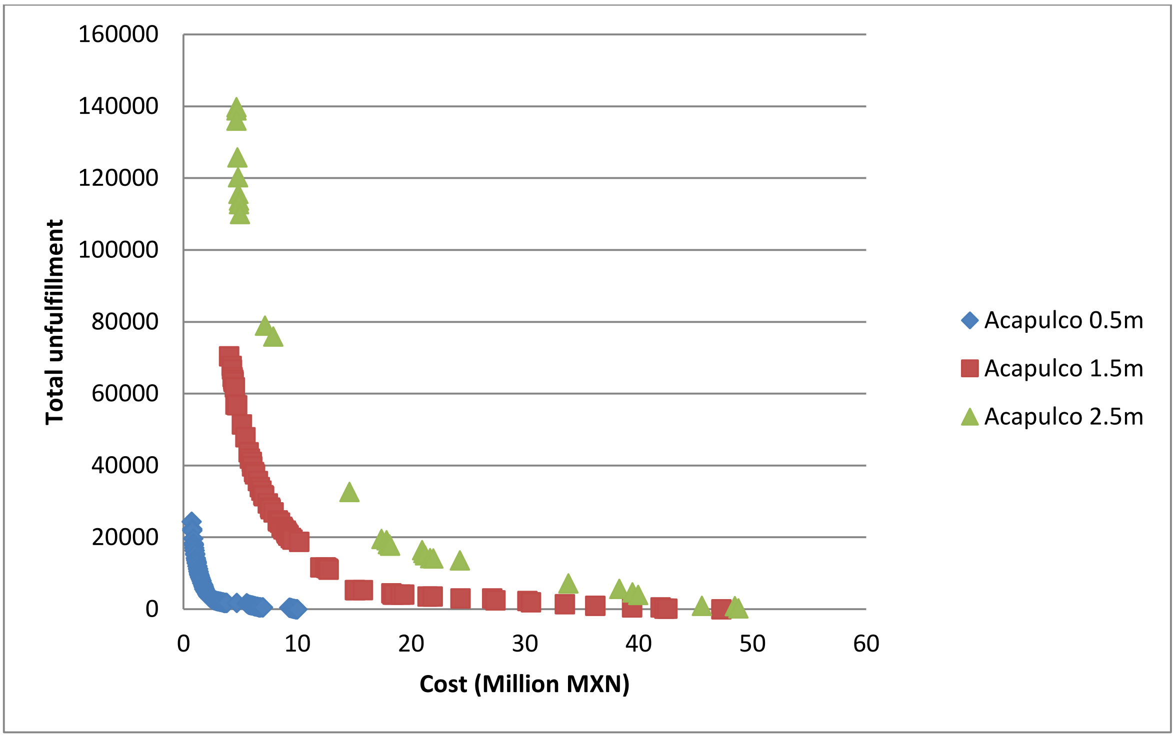

Figure 6.22. Pareto frontier of the three scenarios for response in Acapulco

Table 6.21 exhibits the comparison of metrics between the three scenarios, summarising the main performance measures considered. From the results, it is noticeable that authorities count with enough capacity to handle all of the scenarios presented. The number of agencies actually needed to manage all of the situations is lower than the number of organisations involved in the disaster situation, pointing towards room for improvement for future events. The complete set of results can be seen on Appendix G.

Table 6.21. Performance measures of the results obtained for response for the scenarios in Acapulco

Flood depth	**Cost (MXN)**		**Maximum agencies per period**	**Maximum Fill Rate (%)**						
	Min	*Max*		Food	Med	CKIT	PKIT	HKIT	NVH	NVS
0.5 meters	728,638.38	9,998,732.82	6	100	100	100	100	100	100	100
1.5 meters	3,855,340.13	46,725,583.36	8	100	100	100	100	100	100	100
2.5 meters	4,658,644.07	48,777,316.49	7	100	100	100	100	97.27	100	100

6.2.4.3 Discussion of the results of the three response scenarios at Acapulco

Tables G.10, G.11 and G.12 contain the metrics for the set of efficient solutions for each one of the three scenarios, ranging from cost-effective to service oriented policies. The results show that the amount of resources available for disaster response in terms of products and services seems adequate, contrary to the results drawn from the preparedness model.

None of the scenarios requires eleven organisations involved, showing that the number employed on the flood of 2013 was more than actually needed. The model is increasing/decreasing the number of organisations required depending on the scale of the event, maintaining only necessary resources on the field. Overall there is an excess of personnel and vehicles for the conditions described on the three scenarios.

Ranging from low to high cost, there is an emphasis on medicines followed by food pantries and hygiene kits, the latter because of the relationship between cost and service. Cleaning kits and personal kits are supplied on more service oriented solutions given their priority.

For the first scenario, all solutions are providing high percentage of fill rate for medicines. The reason is because of the low number required given the prior distribution provided by the preparedness policy on most of the shelters and the lifetime of the kit of one month. Discussing the services, shelter attention takes precedence over healthcare on the three scenarios given the dominance of operative personnel in contrast to healthcare personnel.

Although on the third scenario there are higher levels of inventory, in general the model pushed the relief towards shelters. Having to make fewer trips is convenient from the point of view of expenses and need for resources, both for DCs and distribution, but the result was in general unforeseen.

To sum up, the results obtained provided coherent solutions in line with the rationale behind the design of the model. The results show potential advantages for the efficient use of resources by using the response model proposed.

6.2.4.4 Solutions selected for the three response cases in Acapulco

The decision maker operated with a strong focus on fill rate but looking for a good value in terms of cost. Analysing the Pareto frontier of every scenario and looking at the solutions presented on Appendix G, the efficient points summarized on Table 6.22 were selected.

Table 6.22. Metrics of the solutions chosen for the three response scenarios in Acapulco

Sol	Cost (MXN)	Maximum number of agencies per period	Fill Rate (%)							Maximum number of human resources per period		Maximum number of vehicles per period	
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health	Total	Trips
101	6,575,715	4	100	100	99.5	100	100	95	99.8	269	41	5	10

46	25,461,547	7	100	100	100	100	100	90.1	100	1534	127	73	122
24	33,837,350	7	100	100	100	100	96.5	88.9	100	1647	217	39	239

All of the solutions are far away from expensive solutions, not reaching even 70% of the maximum cost. Nonetheless, the values of fill rate are very close to total fulfillment.

6.3 Villahermosa, Tabasco

Figure 6.23 shows an image of the city of Villahermosa, county seat of the Municipality of Centro (CENTRO) and the capital of the state of Tabasco. Villahermosa is located on the coordinates latitude 17°59´ 09.59” N and longitude 92° 55´11.10” W with an altitude of 10 meters above sea level (SEMAR, 2015b).

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Source: Google_Earth (2015)

Figure 6.23. Villahermosa, Tabasco

With a total population of 474,507 people in the last census (INEGI, 2010c), Villahermosa has been declared the “Energy City of Mexico” (WECP, 2015), and the only Energy City in Latin America (SEMAR, 2015b). Nearly with 90% of natural gas produced within 200 km It has excellent connections to the seaports that handle nearly 95% of oil exports from Mexico (WECP, 2015).

The city is in the hydrological region Grijalva-Usumacinta, in the delta created by 3 rivers: Grijalva, Usumacinta and Carrizales as shown on Figure 6.24. Grijalva is the second most abundant river in the country and in combination with the Usumacinta river the total unloading is around 125,000 million m^3, the most significant system in North and Central America, and the 7^{th} globally (SEMAR, 2015b). On top of that, Villahermosa borders with the water body “Laguna de los Espejos” and it is close to “Las Peñitas” dam system, making the city a very prone area to flooding (CEPAL, 2011).

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Figure 6.24. Rivers in Tabasco

Villahermosa has been commonly affected by floods with considerable economic damage in 1975, 1990 (IMTA, 2008), 1999, 2007 and 2008 (CEPAL, 2011), and in 2009 (PNUD, 2009).

6.3.1 Flood of 2007 in Villahermosa

This case is based on a riverine flood. The cold front number 4 caused extraordinary raining of nearly twice the historical average (SEGOB et al., 2008) as seen in the comparison between the rainfall in 2007 (left) and the historic average (right) shown in Figure 6.25. There was over 400 mm of rainfall in 24 hours and nearly 1,000 mm over three days (IMTA, 2008).

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Source: SEGOB et al. (2008)

Figure 6.25. Comparison between the historical averages of rainfall in the month on October between 1946-2006 and October 2007

The rainfall combined with the opening of floodgates of the “Peñitas” dam created a catastrophic situation with nearly 80% of the state covered by water. Water heights of four meters and more than one million people affected were the results (IMTA, 2008). Villahermosa was significantly affected as shown in Figure 6.26, with around 90% of the area covered by water (IFRCRCS, 2007e).

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Source: IMTA (2008)

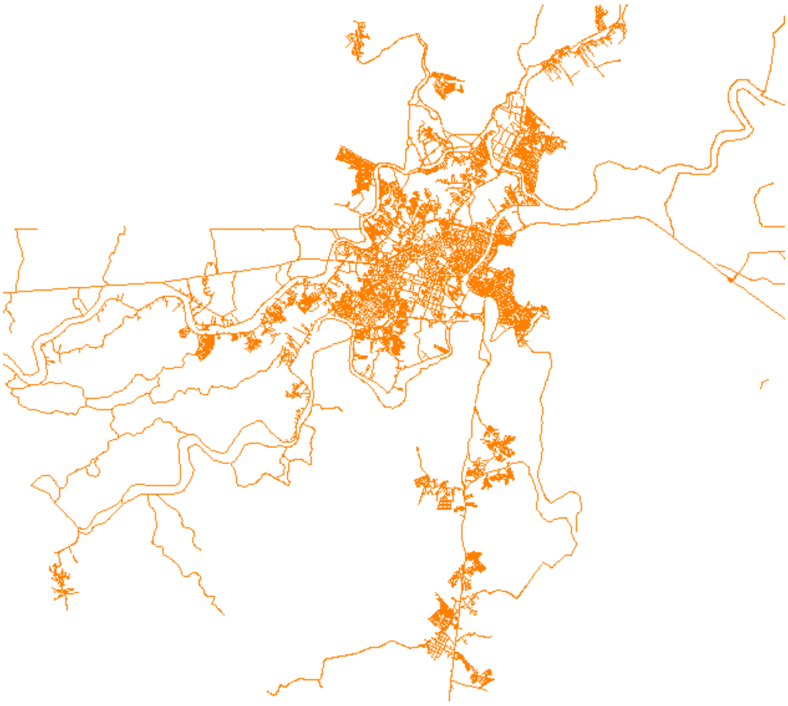
Figure 6.26. Flood of Villahermosa

This flood represented damage estimated in 31,800 million pesos (over 3,100 million dollars) in the state of Tabasco alone; around 29.3% of the GDP of the State (SEGOB et al., 2008).

6.3.2 Application of the GIS procedure on Villahermosa

6.3.2.1 Layers used for the case of Villahermosa

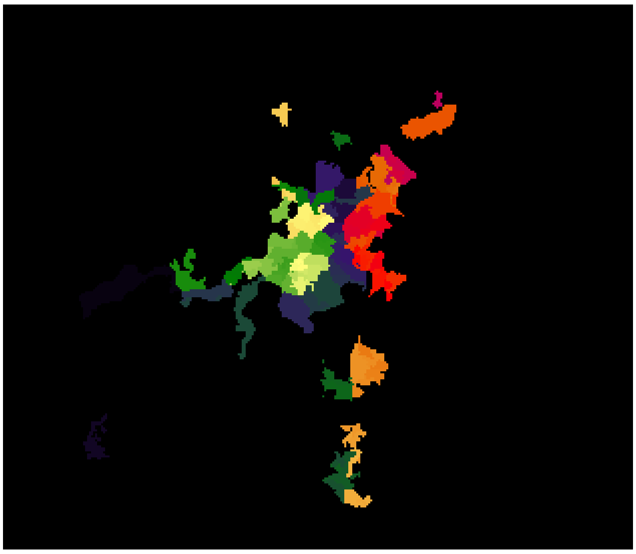
The four main layers used by the geographical procedure include the road network, demand areas, DEM and available facilities. The road network is shown on Figure 6.27 and it was obtained from INEGI (2010c) on *shapefile* format.



Source: Compiled by author with information from INEGI (2010c)

Figure 6.27. Road network of Villahermosa

Figure 6.28 displays the 147 *AGEBs of the city obtained from* INEGI (2010c)*,* with the population of each unit embedded into the layer.



Source: Compiled by author with information from INEGI (2010c)

Figure 6.28. AGEBs existent on Villahermosa

To incorporate the elevation of the area, one DEM from USGS (2010) and another from INEGI (2015) were obtained for comparison. After checking the accuracy of each one through scenario analysis, the decision was to maintain the layer provided by USGS (2010). Villahermosa was found on the edge of two images for the case of INEGI (2015), requiring a merge procedure that could compromise the results around the edges. Figure 6.29 displays the DEM used for the analysis, with a plain region displaying low altitude.

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Source: USGS (2010)

Figure 6.29. Digital elevation model of Villahermosa

The catalogue of facilities of the city contained only 107 shelters with a total capacity of 26,380 people (SEGOB, 2014b), whereas the reported number of people sheltered was around 99,000 people (See PCT, 2014a, ISSET, 2014b, SEDENA, 2014u). Insufficient capacity from planned shelters caused authorities to improvise using whatever facility available including particular houses (See PCT, 2014a). Focusing in the planning component of this project, the decision was made to obtain a list of suitable shelters from public facilities in the city. A list of all facilities in the city was provided by the research group "Modelación de Sistemas Logísticos y de Transporte" (MOSILTRA) from the Universidad Autónoma del Estado de México. The list was created using satellite images with a scale of 1:50,000 of the area, and using TransCAD® to draw the facilities. The list contains georeferenced data from 1,778 facilities in the city including name, type of facility, location and area.

From the list of facilities, all the buildings with an area equal to 0 meters were discarded, yielding 1518 facilities. Then, the list was filtered based on the 38 different types of buildings to include libraries, schools, military facilities, DIF shelters and temples. Next, entries with missing and duplicated data were eliminated. Afterwards, Google Earth® was used to check and correct facilities with suspicious areas, to provide 484 facilities available.

From the space of each building, 60% of the indoor area was considered for dorms and the rest for stairs, hallways, bathrooms, recreational areas, cooking spaces and storage. The number of people that can be sheltered at each facility was obtained using data from Table 5.1. For logistical reasons, facilities with a capacity under 20 people were discarded and the final number of 443 shelters with an aggregated capacity of 164,253 people was used. The complete list of shelters can be checked on Table D.5 on Appendix D.

Regarding DCs, authorities provided available facilities but declared not to have information in terms of capacity of most of them. The list was complemented with one facility available from SEDESOL and 13 public buildings provided by MOSILTRA. The list of 22 facilities with their features can be checked on Table D.6 on Appendix D. The missing capacities were calculated in based to the area of the facility.

An overlap of the layer for shelters and the layer for DCs can be seen on Figure 6.30 with an even distribution across the region.

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Illustration removed for copyright restrictions

Figure 6.30. Facilities available in the region of Villahermosa

6.3.2.2 GIS procedure for the case of Villahermosa

Even though the altitude of the city is stated as 10 meters above sea level (SEMAR, 2015b), trails were run ranging from 0 to 20 meters to identify the altitude were the DEM resembled the actual area, obtaining the result around 6 meters.

The estimated height of water around 4 meters (IMTA, 2008) was used for the creation of the scenario for the real conditions. The decision about the scenarios for this case was based on conditions resembling other situations registered in the region (See PNUD, 2009). The scenarios selected for Villahermosa were floods of 1, 2 and 4 meters.

Applying the cartographic model to the three situations, the images included on Figure 6.31 were obtained.

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Figure 6.31. Flood of 1 meter, 2 meters and 4 meters at Villahermosa

6.3.2.3 Results of the GIS procedure applied to Villahermosa

In terms of damage to shelters and DCs, Figure 6.32 displays the surviving candidate facilities under the three scenarios where the small dots represent candidate shelters and the medium ones represent distribution centres.

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Figure 6.32. Surviving facilities for floods of 1 meter, 2 meters and 4 meters at Villahermosa

From the results of every scenario, Table E.7 on Appendix E includes the list of 368 candidate shelters for the flood of one meter, 340 remaining shelters for a flood of 2 meters of depth, and 282 surviving shelters for the situation of 4 meters of height of water. Similarly, Table E.8 on Appendix E includes the analysis of the DCs available for each one of the scenarios, with 22 surviving facilities for the flood of 1 meter, 20 for the flood of 2 meters and 18 for the worst conditions.

Table 6.23 summarises the results about the damage caused by the floods. Around 68%, 78% and 88% of the AGEBs were affected by the floods of 1 meter, 2 meters and 4 meters respectively. The number of AGEBs damaged over 50% of their total area is more than half of the total of the demand points for the scenario representing real conditions. Details about the damage to each one of the AGEBs can be checked on Table E.9 on Appendix E.

Table 6.23. Summary of level of damage caused by the three scenarios in Villahermosa

Level of damage	1 meter	2 meters	4 meters	Level of damage	1 meter	2 meters	4 meters
Not affected	47	32	18	50<x<60	6	8	15
1<x<10	35	27	14	60<x<70	7	8	12
10<x<20	10	12	8	70<x<80	4	6	10
20<x<30	13	13	11	80<x<90	0	6	13
30<x<40	11	7	6	90<x	8	12	37
40<x<50	6	16	3				

Road connectivity between facilities was determined using the flood maps along with the Floyd-Warshall algorithm. Connectivity for boat transportation was considered opposite to road transportation and air transportation was considered available between all points.

6.3.3 Preparedness optimisation model applied in Villahermosa

6.3.3.1 Data collection for the scenarios on Villahermosa

Most of the data collection was performed using Freedom of Information (FOI) requests submitted to the national information transparency platform and contacting transparency State units. A total of 128 requests to nine National authorities and 134 requests to eight regional authorities were filed, from which details can be checked on Appendix C.

Among the seventeen agencies enquired, CENAPRED, SRE and Universidad Juarez Autónoma de Tabasco were organisations only asked about reports or international aid, whereas SEDESOL declared no jurisdiction or information available. Hence, thirteen agencies were included for the case, and these were Municipality, DICONSA, DIF, IMSS, Social Security Institute of the State of Tabasco (ISSET), PC, SMEXICO, State Health Ministry of Tabasco (STABASCO), Transport and Communications Secretariat (SCT), SEDENA, SEGOB, SEMAR and SSP.

<u>Relief items and product inventory</u>

Food pantries were reported only by DICONSA, with 2,500 products available for distribution in the area and no other products (DICONSA, 2013). In terms of medicines, SS (2014g) declared the availability of 2 kits for 1000 people, whereas SST (2014c) handled 10 kits for 100 people initially. The features of the products distributed after the flood in Villahermosa were available from FONDEN, healthcare organisations and SEGOB et al. (2008). Table 6.2 displays the full list of products and characteristics.

<u>Demand</u>

Using information from INEGI (2000) and INEGI (2010b), the method provided by INEGI (2014) was used to determine the growth rate of 2.098% per year for Villahermosa. The population in Villahermosa at 2007 was interpolated for each one of the AGEBs.

The demand at shelters served by authorities under real conditions was obtained from PC, with a list of 908 sheltering facilities PCT (2014a). From the list, the facilities declared with 0 people sheltered and an unknown number were deleted, along with shelters with incomplete information, leaving 756 facilities. Next, ten houses used as shelters were discarded, as they were not managed by the government. After deleting duplicated entries and aggregating shelters with location on the same neighbourhood with no further information, the cleaned database was integrated by 677 shelters and supplemented with information from ISSET (2014b) to identify the final occupancy of 99,000 people. For the other scenarios a linear relationship was considered between flood depth and people affected, yielding a number of 49,500 and 24,750 people sheltered for floods of 2 meters and 1 meter respectively.

From that information and the expected damage of the flood on the AGEBs, the percentage of people using shelters was multiplied times the number of people affected per demand area to obtain the number of people to serve per origin.

Transportation modes

The magnitude of the flood of 2007 called for the use of all of the transportation modes discussed so far, as shown by Table 6.24.

Table 6.24. Vehicles available in Villahermosa

Organisation	Small trucks	Medium trucks	Large trucks	Boats	Helicopters	Information request
CENTRO	40	0	0	0	0	05923014, 05923214
DICONSA	32	45	27	6	0	2015000001014, 2015000003714, 2015000003914
DIF	2	6	0	0	0	06400114
IMSS	2	0	0	0	0	0064100439014, 0064100439414
PC	16	0	1	0	0	06402814
SMEXICO	12	0	0	0	0	0001200006814
STABASCO	0	32	0	6	0	05923814, 05924014
SEDENA	34	103	5	0	0	0000700002614, 0000700031114, 0000700031314, 0000700106513
SEGOB	2	0	0	0	0	0000400264914
SEMAR	8	0	0	5	3	Press release 148/2007
SSP	0	0	0	0	1	05924414

Shelters

Information from DIF (2014b) was used to obtain a cleaning price of MXN $\$2.42/m^2$, multiplied times the indoors space of each facility to determine cleaning cost. The expenditure on mats, blankets, raincoats, flashlights, water containers and baby tubs was added to the cleaning cost to obtain the preparation cost per shelter shown on Table D.5.

Distribution centres

The cleaning cost of these facilities was considered the only relevant factor for the set-up cost. I was obtained using the price of MXN $\$2.42/m^2$ provided by DIF (2014b) and the indoor area of the premises of the facilities.

Personnel

Considering the limited nature of the responses and the inclusion of the opinion from different authorities, the personnel required for all the activities was assumed to be the same as the case of Acapulco, explained on Section 6.2.3.1.

Table 6.25 shows the personal available per agency and activity to be considerably larger than the number of employees in the other cases, due to the magnitude of the event.

Table 6.25. Number of employees per activity available in Villahermosa

Agency	DC	Shelter	Healthcare (teams)	Distribution	Total personnel	Information request
DICONSA	150	0	0	150	150	2015000001314, 2015000003814, 2015000004014
DIF	40	40	0	40	40	06399914
IMSS	0	0	14	0	14	0064100438914
ISSET	0	0	9	0	9	06644914
PC	50	50	0	50	50	06402614, 06402714
SMEXICO	0	0	2769	0	2769	0001200006714
STABASCO	0	0	347	0	347	06400314
SCT	30	30	0	30	30	06243714
SEDENA	8697	8697	0	8697	8697	0000700031014, 0000700144314, 0000700106513
SEGOB	18	18	0	18	18	0000400264914
SEMAR	510	510	0	510	510	Press release 148/2007
SSP	3779	3779	11	3779	3790	05924314

Information from the transparency information system, regional agencies for State organisations and salary tables provided by SHCP was used to determine the income for operative personnel. The earnings of healthcare teams were obtained with information from the State transparency information system and the salary table available at: http://salud.edomexico.gob.mx/html/transparencia/informacion/tabulador/Tabulador_Sueldos.pdf, aggregating the income of healthcare teams. Table 6.26 displays the wages considered for the application of the preparedness model in Villahermosa

Table 6.26. Wages per organisation for a flood in Villahermosa

Agency	Type of personnel	Number of employees	Wage (MXN)	Total wage (MXN)
DICONSA	Operative	150	1,154.251	173,137.6
	Healthcare	0	-	
DIF	Operative	40	906.708	36268.32
	Healthcare	0	-	
IMSS	Operative	0	-	150,824.1
	Healthcare	14	10,773.15	
ISSET	Operative	0	-	88,603.14
	Healthcare	9	9,844.793	
PC	Operative	50	844.068	42,203.4
	Healthcare	0	-	
SMEXICO	Operative	0	-	31,399,352
	Healthcare	2769	11,339.6	
STABASCO	Operative	0	-	3,934,841
	Healthcare	347	11,339.6	
SCT	Operative	30	877.7613	26,332.84
	Healthcare	0	-	
SEDENA	Operative	8697	1,283.467	11,162,310

	Healthcare	0	-	
SEGOB	Operative	18	783.476	14,102.57
	Healthcare	0	-	
SEMAR	Operative	510	1,283.467	654,568
	Healthcare	0	-	
SSP	Operative	3779	825.492	3,164,936
	Healthcare	11	4,127.46	

Distance matrices

A layer of centroids was created and merged with the layers of facilities in order *to obtain both road and Euclidian distances for land and boat/air transportation respectively.*

The shipment cost was estimated as the multiplication of two times the distance between facilities times the cost per mile of the transportation mode considering the cost per mile for the vehicles included on Table 6.4 and Table 6.14.

A threshold of 10 miles was considered given the features of the area and different trials to create the coverage matrix.

6.3.3.2 Application of the preparedness model to the three scenarios in Villahermosa

The weighted-sum method and the ε-constraint method were used for 200 iterations each. The complexity of this situation required further analysis for solution time. After different trials solution time was increased to 3,000 seconds for the first two scenarios and 3,600 seconds for the third scenario, emphasising the importance of the real case. After filtering only efficient solutions, Figure 6.33 depicts 68 efficient points for the first scenario, 66 solutions for a flood of 2 meters and 149 non-dominated points for the emulation of the real case.

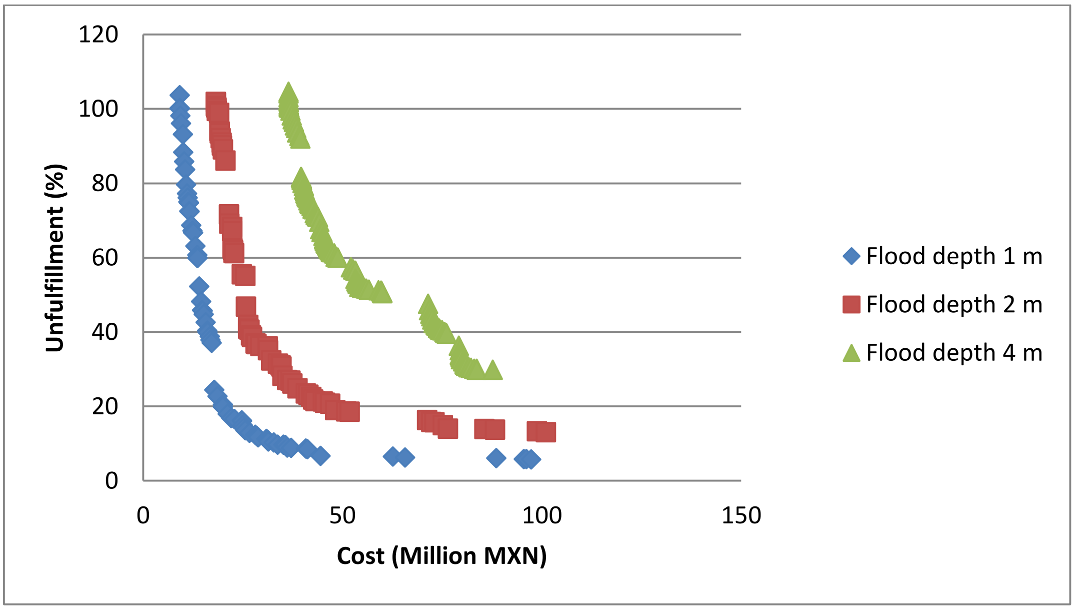


Figure 6.33. Pareto frontier of the three scenarios for preparedness in Villahermosa

The details of each one of the points obtained can be checked on Appendix G. Table 6.27 contains a summary of the results obtained for each one of the scenarios. There seems to be enough human resources to satisfy the requirement of services after the floods, but not nearly enough relief items to cope with any of the situations.

Table 6.27. Overview of the results of the efficient points of the three scenarios in Villahermosa

Flood	Cost		Maximum agencies	Maximum Fill Rate (%)				Shelters		Maximum DCs
	Min	Max		Food	Med	NVH	NVS	Min	Max	
1 m	9,124,407.22	97,366,177.97	13	40.4	11.77	99.86	100	27	223	20
2 m	18,235,309.62	101,025,616	13	20.21	5.51	99.33	100	55	340	12
4 m	36,453,514.79	87,674,403.94	12	10.1	2.87	99.99	99.97	132	251	14

6.3.3.3 Discussion of the results of the three preparedness scenarios in Villahermosa

Tables G.13, G.14 and G.15 show the expected conflict between objectives, with a good range of solutions for the three scenarios. Apparently the maximum cost of the worst scenario is less than the others. The reason a 'more expensive' solution is not portrayed on the image is twofold. Firstly because of the matter of dominance, as the model yielded solutions over 90 million MXN but none of them increased the fill rate; i.e. those were dominated solutions. Secondly, the combination in conditions; the system was reaching its limit in terms of resources at the same time the number of possible facilities was reducing. For instance, the maximum number of shelters opened on the second scenario is higher than the 282 candidate facilities for the third. The same happened for DCs with respect of the first scenario. As a result facility and distribution cost increased.

Focusing on the third scenario, having 12 agencies would sound close enough to the 13 agencies used. That would imply adequate use of resources from authorities. Although that is a reasonable judgement, it is important to clarify the agency unused. Looking at low cost solutions, SMEXICO is deactivated, organisation representing more than 80% of the healthcare employees. For service-oriented points, SSP is discarded even though it embodies nearly 29% of all operative personnel available. The meaning of this is that the number of agencies for this particular disaster was acceptable, but still a large portion of human resources available were not used.

The Min-Max measure seems to be closing the gap between the best and worst fill rate, with averages getting closer to the maximum when moving towards more service-oriented solutions, i.e. most shelters are incurring in similar values.

Contrary to the other cases, the model is looking to satisfy first the need of food and then the requirements of medicines. This is because only two agencies declared availability of medicine kits. These organisations are the second and the third more expensive organisations, thus only used on more service-oriented solutions. On the other hand, as expected, shelter attention is prioritised for low-cost solutions over healthcare.

Looking at the number of facilities in reality, emphasis on planning should be advised given that the model provided support for the same number of people in fewer facilities.

According to the results, evacuation would represent between 5.65 and 6.35 miles per person, which seems a challenging value. It will be discussed further on Chapter 7 along with the assessment of the performance of the model.

6.3.3.4 Solutions selected for the three preparedness cases in Villahermosa

The author of this dissertation operated as decision-maker with a high focus on fill rate, the number of facilities, use of resources, and lastly cost. After checking the solutions included on Appendix G and the options proposed to the supervisors, the policies with the metrics displayed on Table 6.28 were chosen.

Table 6.28. Metrics of the solutions chosen for the three cases in Villahermosa

Depth	Sol	Cost (MXN)	Org	Fill Rate (%)				Facilities		Human resources used (%)		Vehicles used	
				Food	Med	NVH	NVS	Shel.	DCs	Operative	Healthcare	Total	Trips
1 m	64	65,686,294	12	40.36	3.45	97.25	98.63	153	11	93.10	100	31	136
2 m	62	76,447,823	6	20.21	2.67	98.75	99.64	148	6	98.15	99.96	31	99
4 m	138	80,643,186	4	10.06	2.02	99.94	99.67	152	8	100	100	25	117

6.3.4 Response optimisation model applied on Villahermosa

6.3.4.1 Data collection for the three cases on Villahermosa

The magnitude of the disaster in Villahermosa attracted a significant number of actors. Besides the 13 organisations already introduced, other organisations were contacted enquiring for reports about their involvement in relief activities. Reports online and press releases were gathered as well (some available on http://reliefweb.int/).

The response optimisation model is considering one overarching decision-maker, understanding every organisation incorporated in the database equally important. In this case, the affiliation of the actors contemplated is not relevant, but their resources. This way, the model is not discriminating any of the organisations and it is able to include as many of them as possible according to the information available. When an organisation is incorporated under the umbrella of the model, it is assumed that the organisation is providing the information required, putting its resources to disposal and it is subject to comply with the decision of the overarching authority, which for the case of Mexico is SINAPROC.

Considering the possibility of incorporating non-governmental organisations, information was obtained about organisations different from the government. The result included the Presbyterian Mission Agency (PMA), Action by Churches Together International (ACTI), Aktion Deutschland Hilft (ADH), Samaritan's purse (SP), Malteser, World Vision (WV), Search and Rescue Assistance in Disasters (SRAD), Medical Teams International (MTI), Adventist Development and Relief Agency (ADRA), Americares and the World Food Programme (WFP).

Unfortunately, information of MTI, ADRA, Americares and WFP was incomplete or not useful for the purposes of this research. Regarding the rest of organisations, the information obtained was between one and two reports. As a matter of simplification, the resources from all of these organisations were added as one entry labelled as International Organisations (IO). The model can handle every organisation individually, but given the limited information available, and the actual decision about allowing intervention from organisations other than governmental agencies, the decision was to aggregate all of these actors.

Mexican Red Cross, supported by the International Federation of Red Cross and Red Crescent societies (IFRCRCS) took a major role in this disaster. Information from online reports was added and Table 6.29 shows the resources incorporated in this research.

Table 6.29. Resources provided by Red Cross for the flood of 2007

Product	02-Nov	05-Nov	06-Nov	14-Nov	16-Nov	19-Nov	20-Nov
FOOD	1,000	0	29,128	252,071	0	96,081	0
MED	0	0	0	0	0	439	0
CKIT	0	2,000	0	0	1,300	0	850
PKIT	0	0	0	0	0	0	0
HKIT	0	0	0	0	0	0	0
Volunteers	70	650	650	650	650	650	650
Small trucks	166	166	166	166	166	166	166
Large trucks	166	166	166	166	166	166	166
Helicopters	2	2	2	2	2	2	2

Source: Compiled by author with information from IFRCRCS (2007a), IFRCRCS (2007b), IFRCRCS (2007c), IFRCRCS (2007d), IFRCRCS (2007e), IFRCRCS (2008), Government_Mexico (2007b) and Government_Mexico (2007c)

Revising the contribution of other organisations, PMA (2007) and ACTI (2008) provided reports that were cross-referenced about the activities of PMA. ADH participated on the flood by sending 3 tons of medicines to Villahermosa (ADH, 2007), whereas SP reached 3,500 families with food and hygiene kits (SP, 2007b, SP, 2007a). Malteser provided ten tons of food, hygiene products and livelihood support (Malteser, 2007). It was assumed that $\frac{2}{3}$ of the shipment were hygiene and food kits, with the same number of items between both products. Also, according to WV (2007), this organisation delivered 40 tons of contents of cleaning and dispensable kits, which were considered for the equal distribution of cleaning, personal and disposable kits. Table 6.30 displays the relief contributions from these agencies.

Table 6.30. Relief products provided by International Organisations for the flood of 2007

Product	PMA	Malteser	SP	WV	ADRA	ADH
Date	Divided in the first four weeks	November 9th	November 9th	November 3rd	November 5th	November 5th
FOOD	11,381	584	3500	0	0	1648
MED	26	0	0	0	164	0
CKIT	500	584	0	4,145	0	0
PKIT	0	584	3500	4,145	0	0
HKIT	0	584	0	4,145	0	0

Finally, 54 Cuban doctors were sent to provide healthcare support (Government_Mexico, 2007a), and the British organization SRAD provided 10 inflatable boats (OCHA, 2007a).

As this situation challenged the limits of Mexican relief response, it was necessary to ask for international aid. The list was obtained from SRE (2014). For the purposes of this research, only donations from products described in Table 6.10 were included; this can be checked on Appendix I. Considering the reluctance of Mexican authorities to accept this kind of aid except for extreme cases, this information was only available for the flood of 4 meters.

Because of data unavailable, the same number of personnel and vehicles included on the preparedness model was considered available for every period. For the case of Red Cross, the information for the salary of one paramedic was obtained from http://salud.edomexico.gob.mx/html/transparencia/informacion/tabulador/Tabulador_Sueldos.pdf. The doctors from Cuba were assumed to be sponsored by their own government.

Establishing 4 days per period, a total of 16 periods were considered for the analysis to provide support for the 63 days of disaster (SEGOB et al., 2008). The same number of periods was considered for the situations generated by floods of 1 and 2 meters. Only one day was considered for relief distribution.

Demand areas

The demand areas included in the analysis were only shelters. The storage capacity of shelters was obtained using the assumption of 0.5 square meters available for storage per person at each facility, delivering the results shown on Table D.5 on Appendix D.

The evolution of demand over all periods was analysed using information from SEGOB et al. (2008). The relative percentage of people attending shelters per day was obtained and it was projected to the total number of evacuees. The results can be seen on Appendix H.

Relief items

The products described on Table 6.10 were included. Considering the number of people served per item, the demand shown on Appendix H and the initial product inventory, product demand was determined.

Unfortunately the complexity of the case actually hindered the possibility to use the threshold feature; hence the fairness constraint was not activated. In terms of priorities, food and medicines were considered top items with priority values of '3', and '1' for the rest.

DICONSA (2014c) declared the availability of 40,000 food pantries every two periods. For medicine kits, SS (2014g) declared a supply capacity in average of 80 kits per month for the purposes of this research. The contributions from other agencies shown on Tables 6.29 and 6.30 were also included. Finally, public information about the items sent available at FONDEN (2007) was used to determine the capacity of FONDEN for other items per period.

6.3.4.2 Application of the response model to three scenarios on Villahermosa

The weighed-sum method and the ε-constraint method were applied in loops of 150 iterations. A time limit of 5,400 seconds was selected for the first two scenarios, and 7,200 seconds for the third scenario, as the complexity of the model was very high in this situation. A total of 91, 44 and 68 efficient solutions were obtained for the floods of 1, 2 and 4 meters, respectively. The Pareto frontier of the three scenarios is shown on Figure 6.34.

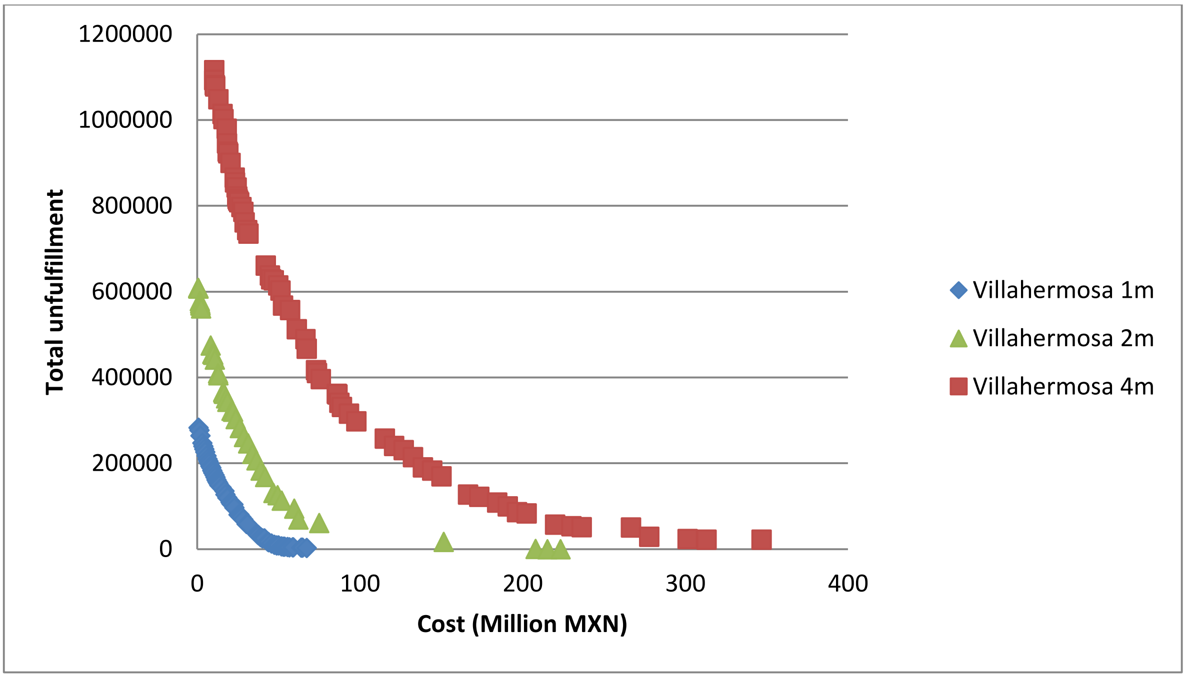


Figure 6.34. Pareto frontier of the three scenarios for response in Villahermosa

Table 6.31 displays a comparison between the three scenarios in terms of different metrics. Authorities count with enough capacity to handle the first two scenarios, whereas relief demand of the third scenario cannot be completely fulfilled. A significant part of that is due to lead time as demand lost on a period cannot be recovered with resources made available later. The number of agencies actually needed to manage all of the situations is lower than the number of organisations involved in the disaster situation, pointing towards room for improvement for future events. The complete set of results can be perused on Appendix G.

Table 6.31. Performance measures of the results obtained for response for the three scenarios in Villahermosa

Flood depth	Cost (MXN)		Maximum agencies p/ period	Maximum Fill Rate (%)						
	Min	*Max*		Food	Med	CKIT	PKIT	HKIT	NVH	NVS
1 meter	50,370.89	91,848,000	9	100	100	100	100	100	100	100
2 meters	636,599.09	223,269,598.47	8	100	100	100	100	100	100	100
4 meters	10,473,088	346,809,889.7	14	100	79.83	80.1	75.3	100	100	100

6.3.4.3 Discussion of the results of the three response scenarios at Villahermosa

Tables G.16, G.17 and G.18 display the metrics for the non-dominated points for each one of the three scenarios identified in the Pareto frontier. The results show that the number of resources available to aid disaster victims in cases of flood in terms of products and services seems ‘adequate’, opposite to the result yielded by the preparedness model. The availability of resources beyond the capacity of Mexican authorities was a significant factor according to the results of the model. The reason the word ‘adequate’ is used is putting in perspective the actual event. From the practical point of view, it can be argued that it was an unprecedented event in terms of magnitude, therefore having enough capacity to satisfy at least 75% of demand of all products, a 100% in some, seems reasonable. Having said that, from the point of view of the numbers there are two major comments. First, the overconfidence on supply capacity from DICONSA (See SSPPC, 2014j) can yield unfortunate circumstances, as the agency could not have supplied enough food for the event. Also, at the end there was oversupply of food but undersupply of cleaning kits. As understandable as this is given the importance of food, more thorough preparation and analysis can aid authorities to find the right balance and avoid convergence of some products and shortage of others.

Results from the third scenario indicate that the number of organisations employed on the flood of 2007 was more than actually needed, probably yielding idle or wasted resources. The model is increasing/decreasing the number of organisations required depending on the scale of the event, keeping only necessary resources on the field. Overall there is an excess of personnel and vehicles for the conditions described on the three scenarios.

Ranging from low to high cost, there is an emphasis on medicines followed by food and the hygiene kits, the latter because of the relationship between cost and service. Cleaning kits and personal kits are supplied on more service oriented solutions. Discussing services, shelter attention takes precedence over healthcare on the three scenarios because of the dominance of operative personnel in contrast to healthcare personnel.

The involvement of International Organisations was successful for this case. Having the information from different actors with resources available to help in the situation, the model was able to incorporate these actors and use their resources as if they were one of the governmental organisations. Including NGOs showed potential to reduce the possibility of duplication of efforts and achieve more efficient operations.

Even though the conditions of the event forced the model to balance a little bit more the levels of inventory between shelters and DCs, there is still a tendency to push the inventories to shelters. It is important to mention that pushing the inventories towards the demand areas can create several complications, even if it provides more space to handle resources on DCs, reduces cost and decreases the chance of convergence or problems for oversupply. The user should bear in mind this tendency of the model, and for the case that behaviour is not acceptable the capacity of demand areas can be reduced or even shutdown.

The results obtained from the application of the response model to the three scenarios provided coherent solutions in line with the rationale behind the design of the model.

6.3.4.4 Solutions selected for the three response cases in Villahermosa

The decision maker operated with a strong focus on fill rate but looking for a good value in terms of cost. Analysing the Pareto frontier of every scenario and the solutions presented on Appendix G, the efficient points summarised on Table 6.32 were chosen. More than 10% away from the most expensive solutions, the points selected provide good fill rates.

Table 6.32. Metrics of the solutions chosen for the three response scenarios in Villahermosa

Sol	Cost (MXN)	Maximum number of agencies per period	Fill Rate (%)							Maximum human resources per period		Maximum vehicles per period	
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health	Total	Trips
1-83	53,000,497	8	100	100	100	100	100	94.8	99.5	2,644	364	49	264
2-41	207,980,805	7	100	100	97.4	100	100	100	99.9	5,148	2,809	632	1475
3-66	301,472,965	10	100	78.6	71.3	74.9	100	100	99.9	16,886	2,796	203	705

6.4 Final remarks about the results of the chapter

This chapter has introduced the application and the results obtained for the three case studies. From the geographical procedure it can be concluded that the simplicity in application allows the user to perform scenario analysis very rapidly, obtaining flood maps to analyse the damage to the area. The results from the cartographic model were particularly useful to determine the availability of facilities and damage caused by the event. The procedure was suitable for coastal floods in Acapulco and Veracruz, and a riverine flood in Villahermosa. It was used under mountain conditions in Acapulco, a flat area in Villahermosa and a case combining both at Veracruz.

The preparedness model can be solved very quickly using optimisation software for small and medium-scale situations. However, time increased considerably for the large-scale case.

About the preparedness model, the measure of fairness proved to be very useful for excess of resources and also for shortages. From the results, it seems authorities count with enough capacity to deal with the situations presented regarding human resources, up to the point that the model identified oversupply in some cases. As a matter of fact, on none of the cases considering real conditions the model used all of the agencies activated there. On the other hand, shortage of resources on some scenarios such as Acapulco and Villahermosa draw attention to the need to analyse further the prepositioning policy used by authorities.

Similar outcomes were obtained for the response model, with consistent results supporting the ideas embedded into the model. However, there is a tendency to push inventories towards shelters that should be carefully considered depending on the priorities and perspective of the user.

Unfortunately, it was concluded that the measure of fairness for this model can become prohibitive for large-scale conditions. For the other cases, the constraint proved to deliver the expected results. It was noticed that supply is more abundant for response, even to the point where oversupply can become an issue.

6.5 Chapter Summary

The purpose of this chapter was to describe the application of the system designed to three case studies in Mexico, along with an analysis of the results. Each one of the cases was introduced, and then details about data collection and the application of the system were explained. Finally, the results from each one of the instances was presented and discussed.

The next chapter undertakes the assessment of the results obtained according to the research questions of this work. The purpose is to answer these questions and provide a judgement about the overall performance of the system designed.

7 EVALUATION AND DISCUSSION

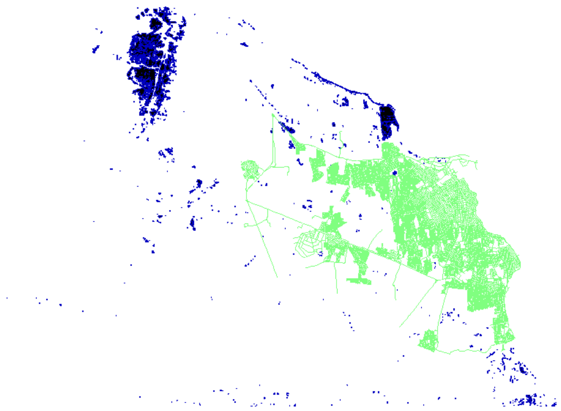
The previous chapter presented details about the application of the system proposed to three case studies in Mexico and the results obtained. The purpose of this chapter is to evaluate that results. The different components of the system will be assessed by comparing them to real data and to other instances aligned to the research questions presented on Section 1.4.

7.1 Results from the geographical procedure

The cartographic model was used to include the geographical dimension of the disaster in the analysis, and to inform the optimisation models. The procedure used for this research comes from the work developed by Martin (1993) and extended by Rodríguez-Espíndola and Gaytán (2015). Therefore, the goal is not to propose a new procedure *per se,* but to show the value of using GIS that can be integrated with optimisation models. Regardless, to show the reliability of the method selected to obtain flood maps, validation of the images derived from the geographical procedure were desired. Each one of the flood maps obtained is analysed considering real conditions to evaluate the outcome of the geographical procedure.

7.1.1 GIS for the case of Veracruz

The flood mask of the disaster in Veracruz in 2010 was obtained from CENAPRED (2014b) and SEMAR (2014e); the former being in charge of disaster information and the latter being the agency in charge of SPOT images of the country until 2013 (SEMAR, 2015a) . Both files obtained are exactly the same, as shown by Figure 7.1. At first glance there seem to be no flood in the region under study, unlike the information gathered. Information about the date of the elaboration of the flood mask was enquired but not made available.



Source: Compiled by author with information from INEGI (2010c), CENAPRED (2014b) and SEMAR (2014e)

Figure 7.1. Flood mask provided by Mexican authorities about the disaster of 2010 in Veracruz

Appendix J contains a set of images obtained from Google® and Flickr® for the dates of the flood, which suggest that the region was indeed affected by the flood. Using the webpage of the Earth Observatory from NASA (http://earthobservatory.nasa.gov/), a MODIS (Moderate

Resolution Imaging Spectroradiometer) from aircraft Terra of September 18th was obtained (See NASA, 2010a). The image of the flood is contrasted with another one from September 17th, 2009 on Figure 7.2, to understand better the impact of the flood in the area under study.

Aston University

Illustration removed for copyright restrictions

Source: NASA (2010a)

Figure 7.2. MODIS image from the Terra Satellite of the southeast region of Mexico on September 20th, 2010

Navy blue (dark color) represents the flood in the region. Importing the image into IDRISI® and enhancing the contrast, Figure 7.3 shows the comparison of the real flood in the region Veracruz-Boca del Río and the results of the geographical procedure employed in this research. The flooded area is very similar in both shape and extension in the centre and south of the region, although with slightly more damage on the west side of the region and a non-existent 'disconnection' of the "San Juan de Ulua" fortress on the north.

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Illustration removed for copyright restrictions

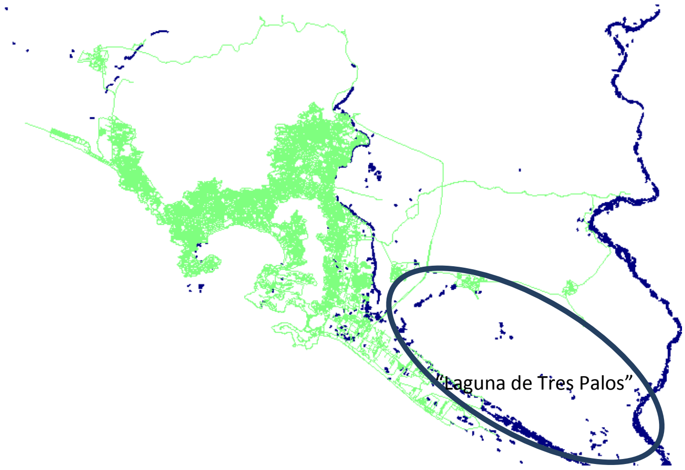
Source: NASA (2010a)

Figure 7.3. Comparison of the flood map obtained and the real flood in Veracruz, 2010

Overall, the system provided an image that resembled the actual flood according to the image presented. Hence, the results were deemed appropriate to continue with the analysis.

7.1.2 GIS for the case of Acapulco

Images from the flood were provided by the Marines (See SEMAR, 2014e) and CENAPRED (See CENAPRED, 2014a). Both files contained the same flood mask, showed on Figure 7.4.



Source: Compiled by author with information from INEGI (2010c), CENAPRED (2014a) and SEMAR (2014e)

Figure 7.4. Flood mask provided by Mexican authorities about the disaster of 2013 in Acapulco

In the image the flood was not really significant for most of the city as the line crossing from north to south near the city is a river. Not even the lagoon in the south seems to be flooded.

Being the image from September 21st, the effect of the flood could have not being evaluated properly three days after the event. To get a better perspective, a search for images of the flood was performed and shown on Appendix J. The results show damage around the southeast of the region near "Laguna de Tres Palos" and near the airport.

Unfortunately, satellite pictures of the event could not be obtained from NASA, but the general shape of the area can be identified on Figure 7.5 as baseline for comparison.

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Illustration removed for copyright restrictions

Source: NASA (2013)

Figure 7.5. MODIS image of Acapulco on December 18th, 2013

An infrared image from the event made available by Pedrozo-Acuña et al. (2014) was used to analyse the damage caused by the flood. Figure 7.6 shows the comparison of that image and the result from the GIS procedure. The flood in the centre-east of the city identified by the GIS procedure resembles the infrared image of the flood, whereas on the southeast the procedure suggested damage near the airport that appears to be non-existent. The reason was the low altitude in the area compared to the rest of the city, causing the region to appear flooded even if in reality there were other factors preventing it to be flooded.

Aston University

Illustration removed for copyright restrictions

Source: Pedrozo-Acuña et al. (2014)

Figure 7.6. Comparison of the flood of 2013 in Acapulco and the image obtained by the GIS procedure

The system showed that considerable variations in altitude can yield false positives in the analysis. The geographical procedure overestimated the flood in the southeast region but provided appropriate results for the area closer to the centre. The overestimation discarded three shelters and two DCs in the southeast area.

Pictures showed on Appendix J combined with the analysis performed by Pamela et al. (2015) shown on Figure 7.7 suggest flood damage in the area of the airport. The date of the picture is early-on in the disaster. That combined with the level of reflection of water under the infrared image can be arguably factors to consider when judging the result, but for the purposes of this work the false positive in the southeast is acknowledged.

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Illustration removed for copyright restrictions

Source: Pamela et al. (2015)

Figure 7.7. Damage caused by the floods in Acapulco

The simplicity of the procedure poses challenges that can derive in the overestimation of the flood. The user should be careful about application, advisably using images from previous floods to assess the results. Overall, as the discrepancy only affected a total of five facilities, the results were accepted. The rationale is that as a false positive would mean not opening facilities that could be on dry areas, instead of opening facilities that could be in fact flooded.

7.1.3 GIS for the case of Villahermosa

The flood in Villahermosa is the one that affected more people, indicating terrible impact. This flood covered a large proportion of the city and the State, as shown by Figure 7.8.

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Illustration removed for copyright restrictions

Source: (GAC, 2007)

Figure 7.8. Flooded areas near Villahermosa on November 6th, 8th and 10th of 2007

Figure 7.9 displays the impact caused by the flood. The comparison exhibits general damage to the region particularly around Villahermosa (circle) and up north.

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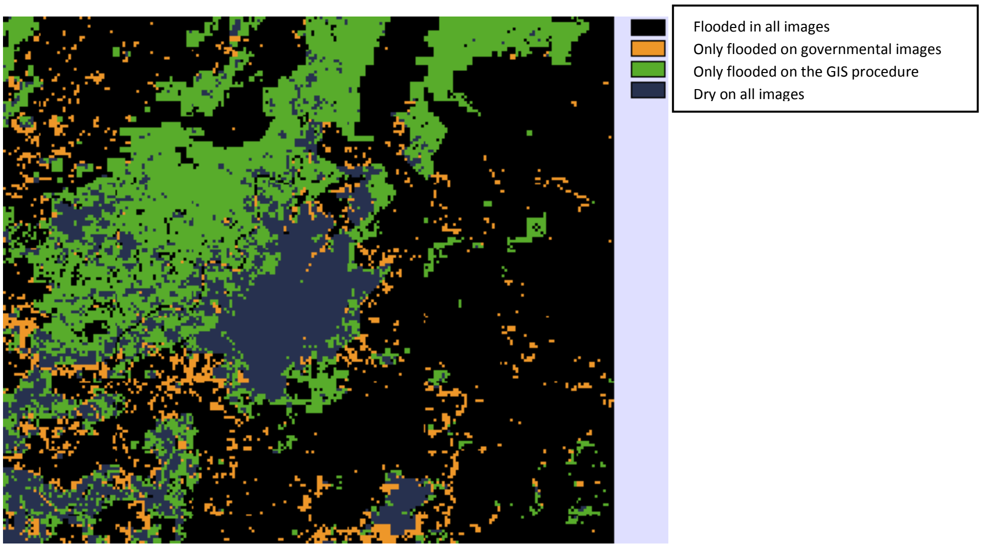
Illustration removed for copyright restrictions

Source: NASA (2007)

Figure 7.9. Satellite image from November 3rd 2007 compared to the area on normal conditions

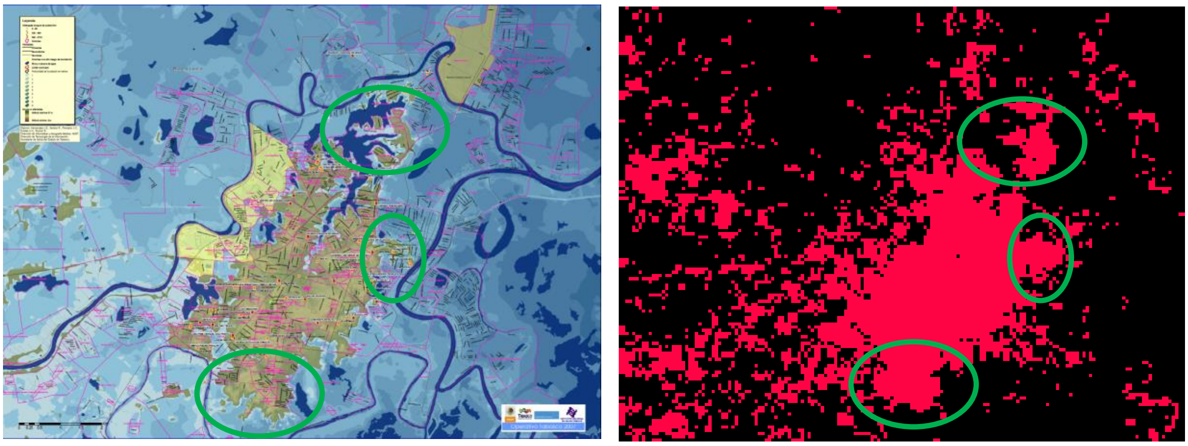
Flood masks from SEMAR (2014a) and CENAPRED (2014c) seemed more realistic in this case. Figure 7.10 displays an overlap of the images from SEMAR and CENAPRED on top of the result from the procedure. Assuming the areas identified by each one of the authorities were flooded at certain point, these should be discarded as facilities could get flooded at some moment. It can be said that the image shows alignment with the combination of both flood masks except for an area in the northwest. There are clear false positives whereas there are small areas with false negatives, but the area of the city seems to comply with the actual event according to SEMAR and CENAPRED.



Source: Compiled by author with information from SEMAR (2014a), CENAPRED (2014c) and INEGI (2010c)

Figure 7.10. Overlap of the images from authorities with the GIS result for Villahermosa

Authorities performed a representation of the flood created based on a digital elevation model from the Health Ministry. The image is compared on Figure 7.11 with the result from the procedure used. Both images exhibit a very similar shape except for the false positive on a region of the west, and another on the northeast called “Medellin y Pigua 3a Sección”.



Source: Compiled by author with information from SS (2007) and INEGI (2010c)

Figure 7.11. Comparison representation of the flood from the Health Ministry and the image from the GIS for the flood of 2007 in Villahermosa

There are very few false negatives that are not affecting any of the facilities identified in this study, whereas constant false positives presented on the northwest of the city along with the partial flooding of the neighbourhood on the northeast state some limitations of the procedure to be addressed in future work. The false positives affected a total of 27 facilities according to the flood masks from authorities. The procedure pointed towards an overflow of river Usumacinta affecting the areas mentioned, something that according to the evidence gathered did not happen. The differences can be attributed to the nature of the GIS procedure, as it relies mostly on the altitude of the area and some zones that are below that altitude can become a false positive.

It can be argued that the overall resemblance to all of the representations from authorities and the satellite images from GAC (2007) taken in the aftermath suggests that the procedure produced a fairly accurate representation of the flood. The system provided results with potential false positives affecting a small number of facilities, and no facilities affected by false negatives. Therefore, the results were deemed appropriate for the analysis.

7.1.4 Discussion and summary of the results from the geographical procedure

The maps created have a tendency to overestimate the actual flood. That is related to the use of altitude as a static baseline for the analysis and disregarding more dynamic factors such as runoff. Having false positives can be a challenge for the user, although the very sporadic appearance of false negatives is a good indication. As a result the maps discarded facilities that perhaps were not flooded; however there were no surviving facilities in floodable areas. It can be argued that the results from the process are valid with the intention to rule out facilities that could be endangered.

In the three maps, the geographical procedure identified the source of the flood and the evolution of it. The maps contained the main areas flooded in each one of the cities.

It is important to highlight how challenging validation was for the cases at hand. Flood maps from authorities were contradicted by satellite images and pictures from the event for the first two cases, with no images from the critical day of the flood for the case of Villahermosa to perform a comparison on the third. Fortunately, the flood masks provided by authorities in the third case seemed more realistic according to the photographs from GAC (2007). More emphasis should be placed for the development of the flood masks to support future work in the area, not leaving aside the importance of the date.

The possibility of considering hydrological factors of the flood is a very important venue for future research. The purpose of this work is not to propose a geographical procedure but to integrate it with optimisation models to incorporate another dimension in the analysis. Even with the limitations mentioned, the results from this section meet the main requirement of discarding floodable facilities for further analysis. Therefore, the results obtained from the geographical procedure were deemed suitable for inclusion into the optimisation models.

7.2 Assessment of the preparedness model

This part elaborates on the assessment of results of the preparedness model, related to the research questions. All of the instances presented in this chapter were solved using GAMS® with Cplex® as a solver on a desktop with an Intel i7 processor and 16 GB of RAM.

7.2.1 Impact of the geographical analysis

Intuitively, it can be said that the use of GIS for disaster management has a lot of potential because of the inherent benefits of incorporating the physical dimension of the disaster. But to date most articles in humanitarian logistics including GIS are focusing on network analysis and data display. Cova (1999) displayed examples of GIS capabilities to provide more support for decision-making.

One of the goals of this research was to investigate analytically the effect of the use of GIS to analyse flood situations on decision-making for facility location. In this part, the results of the three cases presented in Chapter 6 are contrasted with the outcome of the model with the same information but disregarding the results from the GIS.

7.2.1.1 Veracruz

From the results obtained on Section 6.1.2.2, it is known that 3 shelters, one DC and 76 roads would be affected by the flood. Initially, there is a chance of $\frac{3}{44}$ of selecting a floodable shelter and $\frac{1}{10}$ of choosing an inundated DC.

The preparedness optimisation model was applied to the region of Veracruz-Boca del Río for all of the facilities available assuming perfect connectivity between facilities for 50 iterations. The ε-constraint method and weighted-sum method were applied. Figure 7.12 shows the 24 solutions obtained contrasted to the result of the system from Chapter 6.

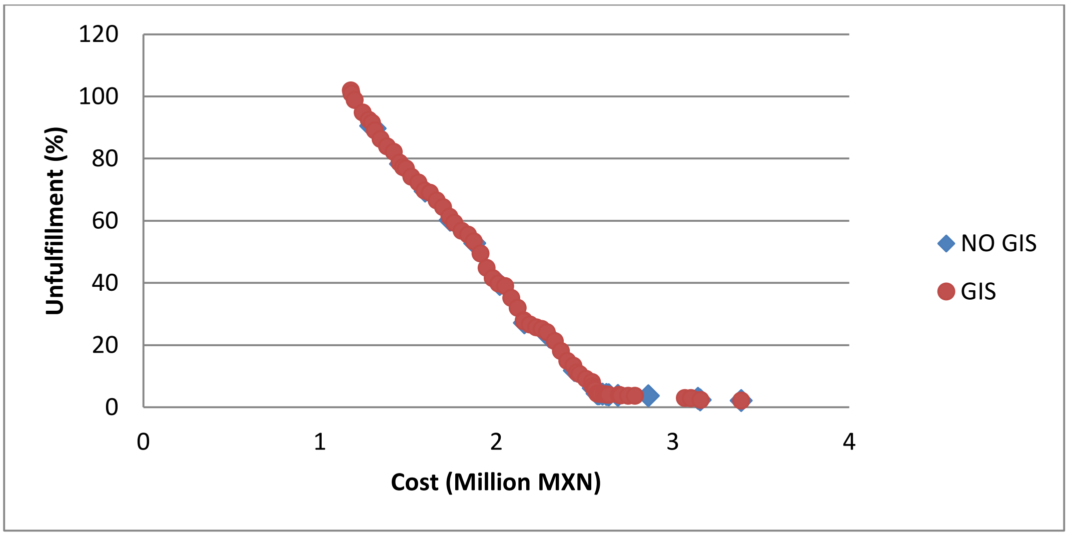


Figure 7.12. Comparison between the results for Veracruz-Boca del Río with and without GIS

The comparison shows no significant difference in the Pareto frontiers. Looking at the numbers, only one solution showed an improvement around 1% in fill rate, whereas for the rest the change was considerably smaller or non-existent.

Table 7.1 shows the number of endangered facilities included in each one of the solutions obtained disregarding the use of the GIS. A little over 58% of the solutions are not including potentially shelters whilst over 83% are not including endangered DCs; which means overall only 54.17% of the solutions obtained did not considered potentially affected facilities.

Table 7.1. Floodable number of facilities selected per scenario in Veracruz

SOLUTION	COST (MXN)	UNFULFILLMENT (%)	SHELTERS ENDANGERED	PEOPLE AT RISK	DCs ENDANGERED
VNG1	1,289,382.25	90.57	2	568	1
VNG2	1,314,943.16	89.71	3	615	1
VNG3	1,457,745.88	78.26	1	62	0
VNG4	1,596,843.04	69.57	2	224	1
VNG5	1,738,612.65	60.23	1	282	0
VNG6	1,879,685.44	52.82	2	352	0
VNG7	2,020,920.35	39.5	2	490	0
VNG8	2,161,081.47	27.18	2	568	0
VNG9	2,302,564.41	22.6	0	0	0
VNG10	2,443,454.81	11.84	0	0	0
VNG11	2,550,565.24	6.22	2	565	0
VNG12	2,572,117.95	4.46	0	0	0
VNG13	2,577,332.72	4.37	0	0	0
VNG14	2,578,529.58	4.33	0	0	0
VNG15	2,584,964.49	4.29	0	0	0
VNG16	2,602,335.43	4.21	1	290	0
VNG17	2,625,476.88	4.12	0	0	0
VNG18	2,636,437.79	4.07	0	0	0
VNG19	2,639,966.91	4.03	0	0	0
VNG20	2,689,884.41	3.86	0	0	0
VNG21	2,862,202.03	3.75	0	0	1
VNG22	3,142,947.2	2.87	0	0	0
VNG23	3,157,023.09	2.43	0	0	0
VNG24	3,388,740.71	2.16	0	0	0

The conclusion is that neglecting the GIS would generate insignificant improvements in terms of time or service, but the probability of wrongfully opening a facility should be reckoned.

7.2.1.2 Acapulco

The GIS procedure yielded four potentially affected shelters and two DCs. The preparedness model was run considering perfect connectivity and availability of all facilities, using the ε-constraint method and weighted-sum method for 50 iterations per method. The 30 non-dominated solutions obtained are contrasted on Figure 7.13 to the Pareto frontier of the solution gotten on Chapter 6. The image shows small variations in the bottom of the frontier below 20% of unfulfillment. The biggest difference yielded an improvement in fill rate up to 4% and nearly $28,000 less. It seems the use of the GIS is worsening slightly the solution.

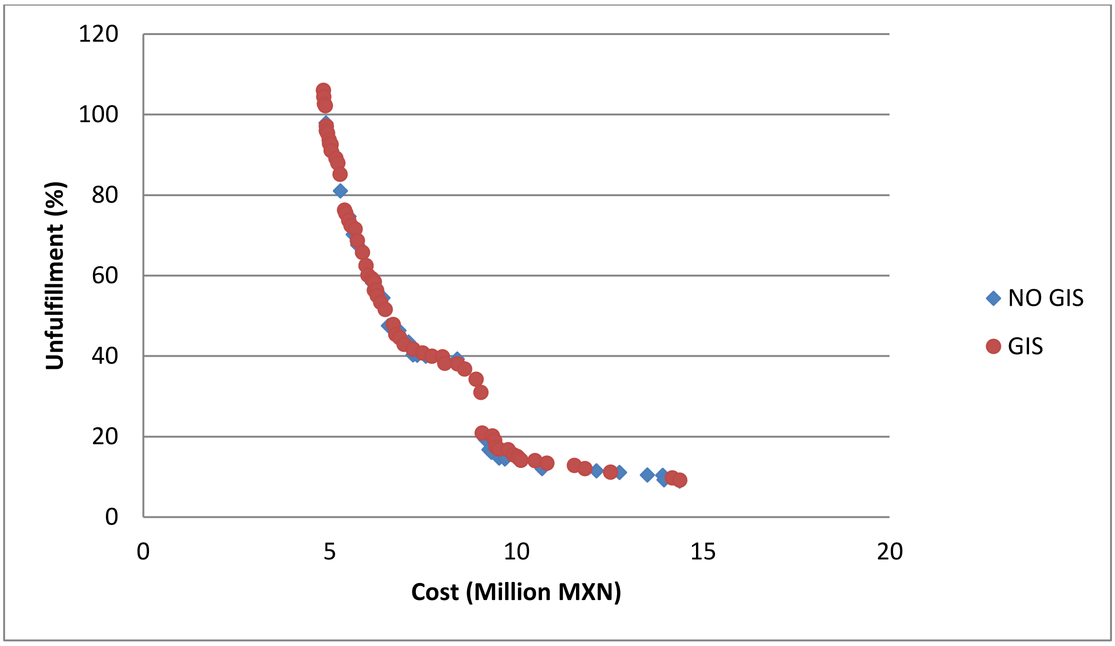


Figure 7.13. Comparison between the results for Acapulco with and without GIS

Table 7.2 shows the number of potentially affected facilities included in each one of the solutions with the stand-alone model. Nearly 46.67% of the solutions incorporated at least one potentially flooded shelter and nearly 16.7% of the solutions included an endangered DC. Overall 56.67% of the solutions involved at least one potentially flooded facility.

Table 7.2. Floodable number of facilities selected per scenario in Acapulco

SOLUTION	COST (MXN)	UNFULFILLMENT (%)	SHELTERS ENDANGERED	PEOPLE ENDANGERED	DCs ENDANGERED
ANG1	4,899,630.78	97.92	1	93	0
ANG2	4,927,089.2	96	3	283	0
ANG3	5,053,114.11	91.06	0	0	0
ANG4	5,287,391.34	81.05	0	0	0
ANG5	5,515,117.52	74.67	3	268	0
ANG6	5,626,150.21	70.22	3	265	0
ANG7	5,746,211.27	67.57	0	0	0
ANG8	5,975,202.5	62	0	0	0
ANG9	6,146,412.67	58.17	3	265	0
ANG10	6,268,300.94	56.11	1	100	0
ANG11	6,427,075.45	54.4	1	93	0
ANG12	6,577,042.14	47.47	3	266	0
ANG13	6,854,297.62	46.32	1	100	0
ANG14	7,118,187.88	43.48	0	0	1
ANG15	7,237,784.87	40.25	0	0	0
ANG16	7,342,048.26	40.19	0	0	0
ANG17	7,579,415.97	39.91	2	90	0
ANG18	8,419,189.43	39.21	1	44	0
ANG19	9,174,669.88	19.29	1	100	0

ANG20	9,266,660.51	16.67	0	0	0
ANG21	9,331,762.16	16.04	0	0	0
ANG22	9,539,621.49	14.67	0	0	0
ANG23	9,694,465.14	14.44	0	0	0
ANG24	10,687,149.38	12.02	0	0	0
ANG25	12,144,912.59	11.49	2	164	1
ANG26	12,766,315.57	11.05	1	100	1
ANG27	13,511,578.71	10.42	0	0	1
ANG28	13,921,040.51	10.34	0	0	1
ANG29	13,958,687.5	9.26	0	0	0
ANG30	14,382,168.01	8.89	0	0	0

It could be argued that the flood map overstated the flood. Assuming the flood as the infrared image presented on Figure 7.5, there would be only one shelter affected by the disaster which would be included in nearly 16.67% of the solutions. Even though that decreases considerably from the previous numbers, the impact is still something to bear in mind for very limited benefits.

7.2.1.3 Villahermosa

A total of 160 shelters and 4 DCs were identified as potentially dangerous in Chapter 4. For this instance 50 iterations were run for the ε-constraint method and weighted-sum method to obtain a total of 25 efficient points shown in Figure 7.14 contrasted to the result of the system. The variation is noticeable particularly between 30% and 50% of fill rate, where the results without GIS have considerable improvements in terms of both cost and fill rate. The solution delivered by the system can be improved up to 8.44% of fill rate and below.

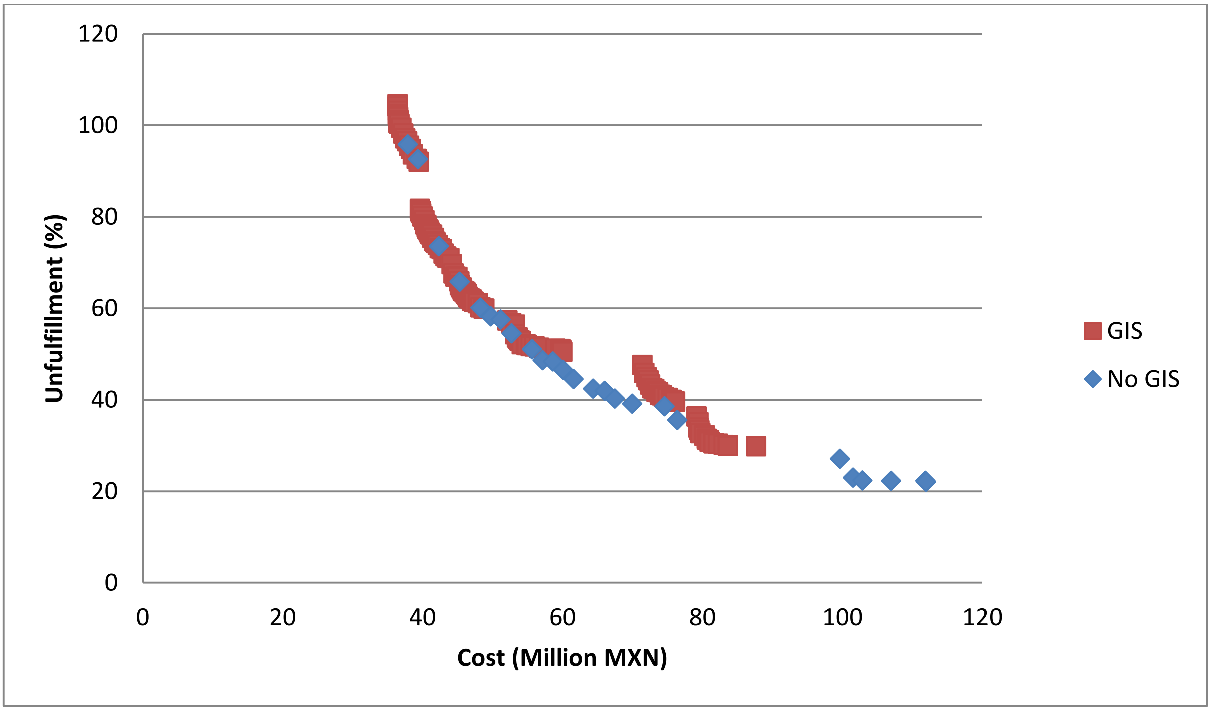


Figure 7.14. Comparison between the results for Villahermosa with and without GIS

Table 7.3 exhibits the number of facilities potentially dangerous included in each one of the solutions. With 100% of the solutions selecting potentially undesirable shelters and 52% choosing endangered DCs, all of the solutions obtained used at least one floodable facility. More importantly, the number of people that is potentially in danger to be allocated in a flooded facility is around 30% of total demand.

Table 7.3. Floodable number of facilities selected per scenario in Villahermosa

SOLUTION	COST (MXN)	UNFULFILLMENT (%)	SHELTERS ENDANGERED	PEOPLE ENDANGERED	DCs ENDANGERED
TNG1	37,912,695	95.79288	60	34,577	0
TNG2	39,393,530	92.64069	55	27,214	0
TNG3	42,348,714	73.58491	59	31,891	0
TNG4	45,312,141	65.80087	62	31,285	0
TNG5	48,281,093	60.11983	61	31,285	0
TNG6	49,754,160	58.25243	73	32,612	0
TNG7	51,202,469	57.53509	66	32,013	0
TNG8	52,724,503	54.55939	65	29,499	0
TNG9	55,651,605	51.02041	89	37,790	0
TNG10	57,165,905	48.65591	55	27,135	0
TNG11	58,648,895	48.3871	38	33,539	1
TNG12	60,125,523	46.58491	60	34,196	1
TNG13	61,601,567	44.54685	60	37,175	0
TNG14	64,412,961	42.46285	80	29,620	1
TNG15	66,035,112	41.97531	82	31,636	1
TNG16	67,533,346	40.23379	89	29,885	1
TNG17	70,001,418	39.17713	104	33,713	2
TNG18	74,611,184	38.61004	106	30,080	3
TNG19	76,422,606	35.58719	88	33,701	1
TNG20	99,705,500	27.14364	85	30,618	0
TNG21	101,569,322	23.00877	79	30,336	1
TNG22	102,882,459	22.32704	96	32,566	2
TNG23	106,992,320	22.2973	94	29,230	2
TNG24	111,912,735	22.25476	160	34,849	3
TNG25	111,979,634	22.05567	160	31,306	2

A very large number of people could be affected in case the results from the geographical procedure would be disregarded looking only at the improvements. For instance, the maximum improvement obtained by disregarding the GIS is 8.44% of fill rate. Focusing on that solution, the number of people potentially benefited would be around 8,358 people, whereas the 104 facilities in risky areas would endanger 33,713 people.

Commenting in terms of the false positives outside of the city, a total of 27 shelters were wrongfully ruled out whereas no DCs were altered. The 27 shelters have a capacity of 13,135 people, showing that for a case where these shelters are all selected and operating at full capacity, still the improvement would not reach the number of people at risk.

7.2.1.4 Summary and discussion

As could be expected, the increase in the flood magnitude also carries out a change on the impact GIS can have on the result. The case of Acapulco is proving how a small number of facilities can actually affect several solutions. On the other hand, Veracruz showed a significant number of solutions incorporating facilities at risk with insignificant improvements.

The situation in Villahermosa provides the best example of the value of the GIS with improvements up to 8.44% of fill rate, but with nearly a third of people at risk. The operation can become notably more costly if the expenditure of opening floodable facilities is combined with the cost of relocating people and activating different facilities, if available.

The use of a tool such as the GIS procedure applied in this research can provide better information for decision-making. Even though the flood maps showed an overestimation of the flood in the case of Acapulco and Villahermosa, the results in this section stand because of the potentially avoided risk achieved by the application of the procedure.

According to the results, on disasters with a low number of facilities affected, the improvements of disregarding the physical conditions of the event are minimal, incurring on higher risk. On the other hand, a test on a large-scale disaster is showing that, even if mistakes in the prediction are accounted for, the risk of using a solution without considering the physical dimension of the event is considerably larger than the potential benefits.

7.2.2 Value of the integrated model

As stated on Chapter 3, even though there is an increasing trend of articles aggregating interconnected decisions there are still a large number of papers focusing on a particular activity within preparedness or response. The former perspective allows the decision to be informed and affected by related activities, whereas the latter allows attaining a higher level of detail. The purpose of this section is to analyse the differences between them for real conditions on the three case studies to provide a conclusion for the preparedness model.

The model proposed was broken down into two models; one for location focusing on minimising cost, and another one for the allocation of resources seeking to maximise fill rate. The location model was in charge of selecting the best facilities to open, whereas the allocation model decided the best combination for the use of resources. The cost of both models was aggregated, whereas only the fill rate from the allocation model was considered. The reason was that the decisions on allocation are the only ones affecting fill rate. For matters of comparison, the same input used for the preparedness model was incorporated into the sequential models developed; i.e. the GIS procedure was included in both cases.

The summary of the results for the three cases can be seen on Table 7.4, showing an adequate performance overall. The elevated occupancy rate of shelters and an adequate fill rate according to the conditions of the situation are the highlights of the results.

Table 7.4. Metrics of the solutions using a combination of a location and an allocation model for the three case studies

Sol	Cost (MXN)	Ag.	Fill Rate (%)				Facilities		Vehicles used	Trips	Shelter avg use	Evacuation
			Food	Med	NVH	NVS	Shelters	DCs				Distance p/person
Ver	6038170	9	100	79.7	100	96.6	15	2	21	68	100	4.39
Aca	11596961	10	71.3	33.3	100	100	46	1	25	65	100	9.22
Vil	87817000	13	10.1	0.1	99.9	99.9	214	2	163	217	100	5.45

To put the results in context, Figure 7.15 displays the position of the results from the sequential model in comparison to the Pareto frontier of Veracruz. The cost from the allocation decisions affected considerably the performance, perhaps indicating the need to incorporate a second objective function based on cost.

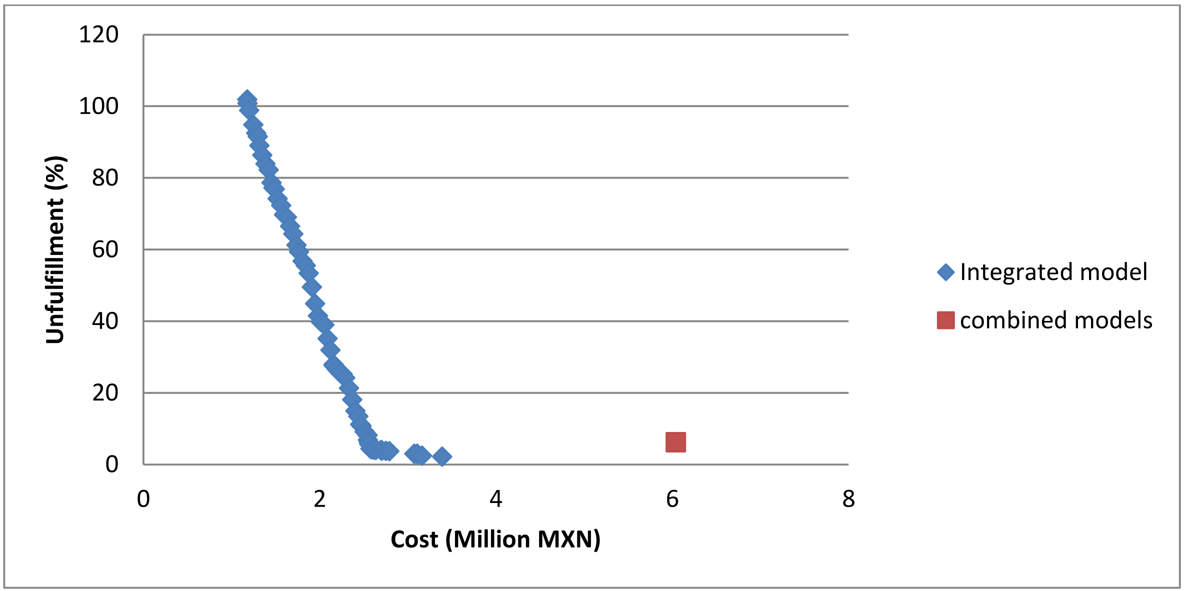


Figure 7.15. Comparison of the results from the integrated model and the sequential approach in Veracruz

The result from the case of Acapulco was also compared to the Pareto frontier obtained from the system as exhibited by Figure 7.16. In this case the performance of the sequential approach was very close to the Pareto frontier. Nevertheless, the point is dominated by the solutions obtained from the integrated model.

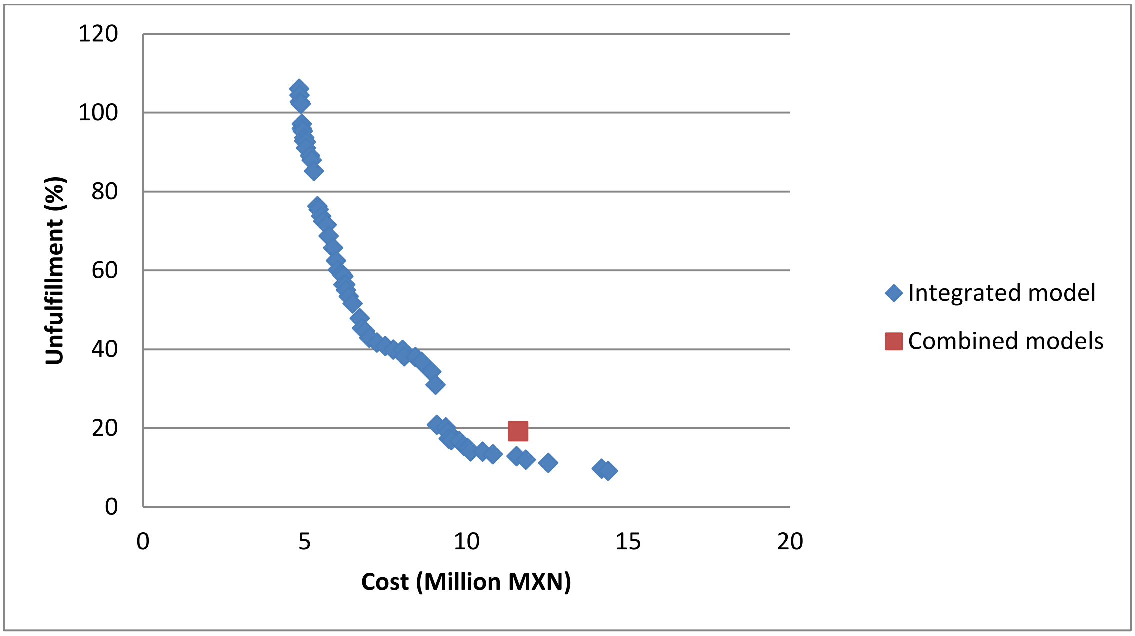


Figure 7.16. Comparison of the results from the integrated model and the sequential approach in Acapulco

Finally, the result from the sequential approach for the flood in Villahermosa was contrasted to the result obtained from the system and showed on Figure 7.17. The overall performance of the combination was close to the Pareto frontier identified for the system. However, once again the outcome of the sequential approach is dominated by the Pareto frontier, demonstrating superiority in performance from the system proposed in this research.

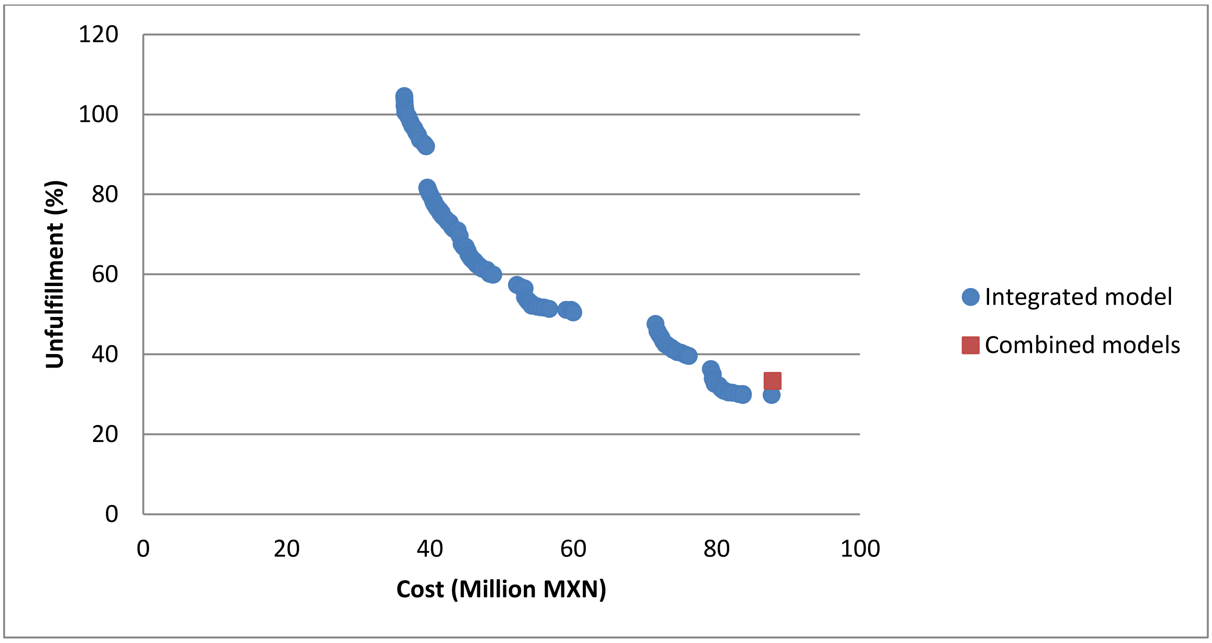


Figure 7.17. Comparison of the results from the integrated model and the sequential approach in Villahermosa

For decision-makers with a service-oriented perspective the sequential perspective can yield some interesting results. The combination of models can provide solutions very quickly because of the single-objective nature of the formulations. However, for the three cases the Pareto frontier obtained using the system designed dominated the results from the sequential models. Furthermore, the Pareto frontiers presented allow the user to identify a solution that can be more appropriate to his/her utility.

The absence of an objective based on cost for the allocation model can cause the use of unnecessary resources thereby elevating expenses. On the other hand, the inclusion of a second objective function would increase the level of complexity, sacrificing time as result.

The main reason the combination of models is not getting the same level of service as the Pareto frontier can be attributed to the independence of decisions. As the location of facilities is being performed without any considerations other than cost, the selection can be optimal from a partial perspective, sacrificing the overall solution. Conversely, the model proposed in this research is balancing not only individual decisions but the relation between them.

Bearing in mind the results showed, the integrated preparedness model seems to be an even more attractive possibility for a broader set of decision makers with a consistent performance over different scale situations than the sequential approach.

7.2.3 Value of the multi-organisational perspective

As stated on Chapter 3, most of the articles in the literature are assuming one decision maker with control over all resources. The problem being that there are only two scenarios where that can be applicable; either each agency run their own model and act according to the results, or resources from all of the organisations are pulled together assuming the involvement of all of them and leaving the allocation of those resources to other decision mechanisms. The former lacks of the possibility to collaborate, whereas the latter allows the use of sub-optimal solutions for allocation and carries the need to involve every actor available. For instance, if there are four agencies with 30 tons of relief each and the model allocates 50 tons in two DCs, the decision-maker would have to make a decision about whose resources to use and where.

Therefore, one scenario presented here focuses on each agency working independently, and another is comparing the results to real decisions from authorities using a coordinated approach. This part investigates the former by using a model for each organisation with the same conditions as the real situations, comparing results with the Pareto frontier obtained with the preparedness model proposed. For this, partial opening of DCs was allowed and operative personnel was assumed as interchangeable.

7.2.3.1 Veracruz

The model was solved for 50 iterations for each one of the nine agencies involved using the ε-constraint method. Table K.1 on Appendix K displays the non-dominated points obtained.

It is assumed that each one of the agencies operated using their resources fully to deal with the emergency, seeking to maximise the level of service provided to the population. Figure 7.18 displays the comparison between the best solution in terms of fill rate attained by each one of the agencies and the Pareto frontier obtained for this case by the system. Evidently none of the agencies has the resources to cope completely with the situation.

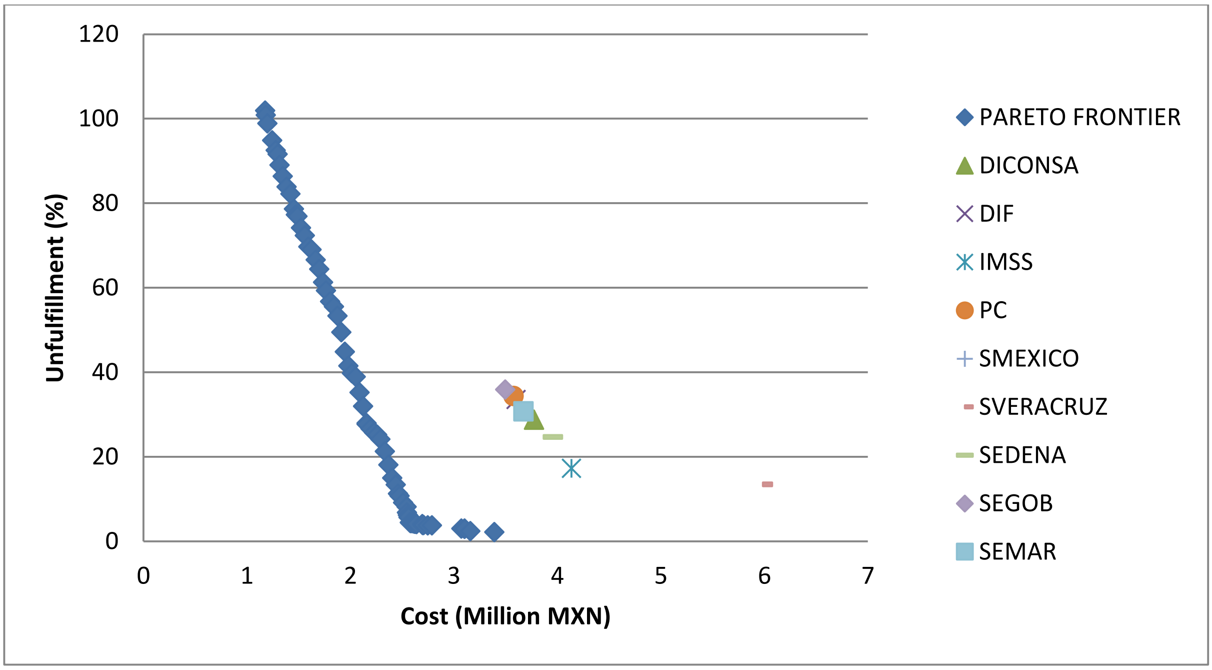


Figure 7.18. Comparison between the results of the system and independent agencies in Veracruz

The figure displays that SVERACRUZ can invest considerable resources beyond the solutions of the Pareto frontier identified but still not to reach the same level of service. The reason is that these organisations rely on each other for supply activities, i.e. health organisations can supply medicines whereas DICONSA provides food and other items. The result stresses the need to coordinate all agencies in order to reach a better solution.

7.2.3.2 Acapulco

Table K.2 on appendix K displays the non-dominated solutions of running 50 iterations using the ε-constraint method for the case of Acapulco. Figure 7.19 shows the comparison between the best solution in terms of fill rate from each one of the agencies and the Pareto frontier obtained for this case from the system. Still there is evidence that none of the agencies can deal with the situation independently.

Again the importance of cooperation between agencies for different aspects plays a major role, as specific resources are only available for certain agencies. Also, disregarding the decisions taken by other agencies is in fact complicating overall operations.

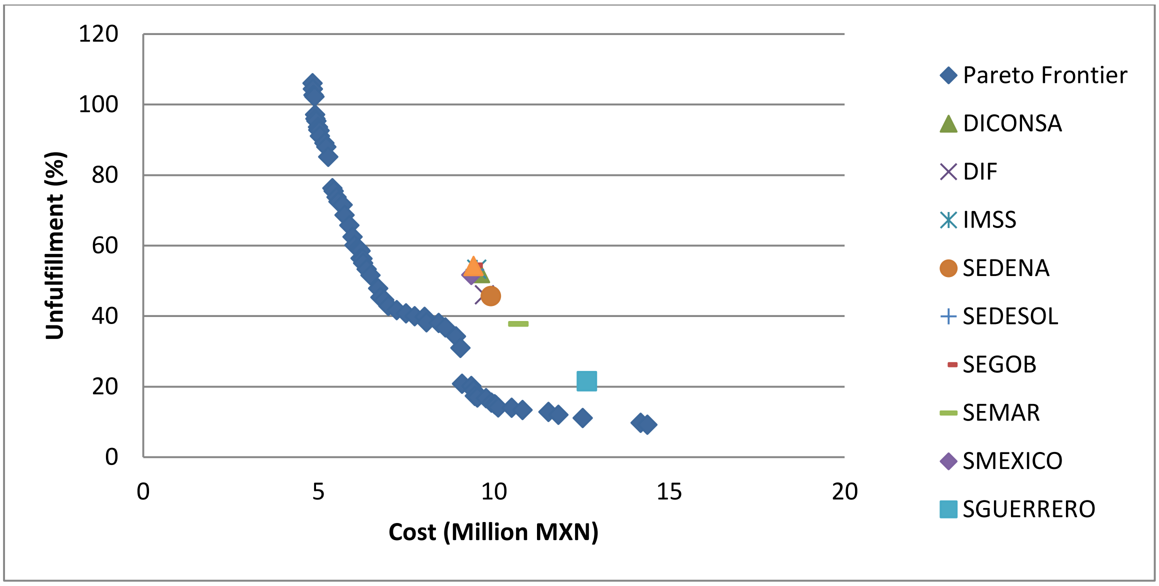


Figure 7.19. Comparison between the results of the system and independent agencies in Acapulco

7.2.3.3 Villahermosa

Incorporating the 13 agencies involved in Villahermosa, the ε-constraint method was applied for 50 iterations. The complete set of solutions can be perused on Table K.3 on Appendix K. Figure 7.20 shows the comparison between the most service-oriented solution for each one of the agencies and result obtained from the system. The performance of individual agencies for this case would be extremely poor, not reaching even 50% of fill rate.

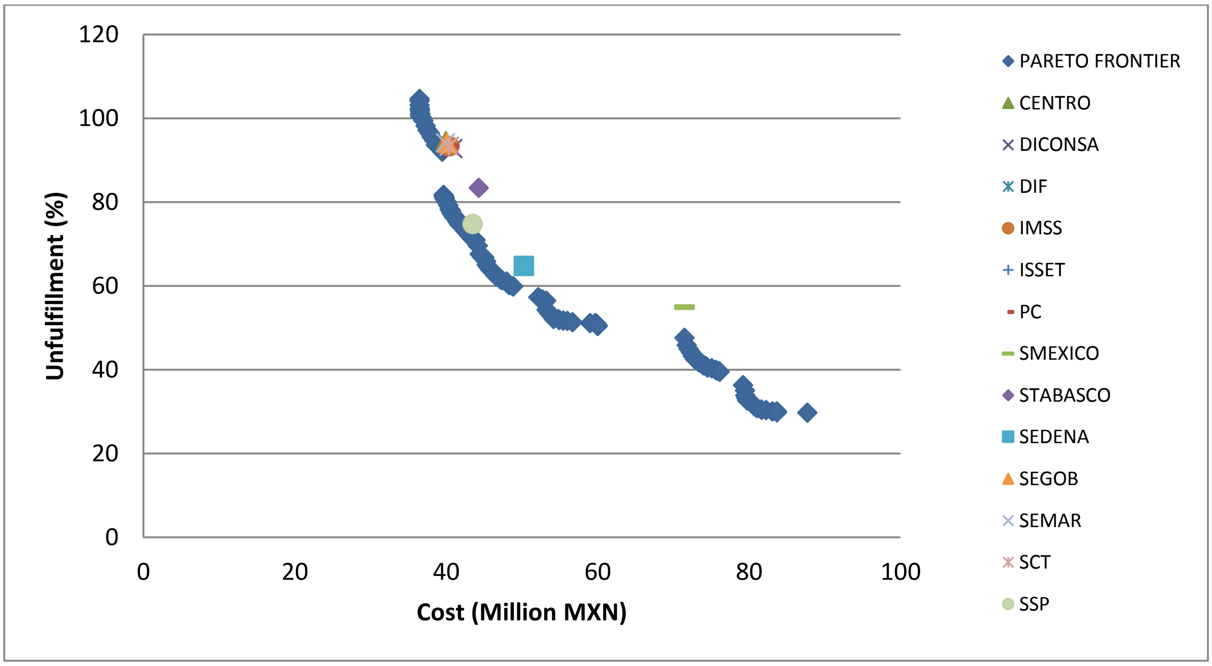


Figure 7.20. Comparison between the results of the system and independent agencies in Villahermosa

This solution is exhibiting that agencies are not prepared to deal with this kind of disaster on their own and that their resources were very limited compared to the dimension of the event. For large scale events individual efforts would faint easily leaving a poorly managed situation.

7.2.3.4 Summary and discussion

The analysis presented in this section confirms that there is no single agency in Mexico with resources to cope with disaster situations. This can be stated as even for ‘small-case’ situations there is an inherent need for different resources brought to the table by different organisations. Indeed, that complementarity is essential to provide a better level of service for disaster victims. This condition becomes stronger as the level of the disaster increases.

Despite disaster planning is intrinsically joined with coordination and independent participation from governmental organisations can seem unrealistic, under real circumstances the complications of coordination can lead to some of them acting on their own. It is important to acknowledge the importance of the participation of different organisations as the underpinning idea for the design of models for disaster operations.

Moreover, coordination among governmental agencies can seem evident, but that is not the case for non-governmental or civil organisations. The same conclusion reached on this part can be extrapolated to those organisations, stressing the need to incorporate them for successful disaster operations. Therefore, a venue for future research is related to the integration of NGOs and civil organisations into disaster planning.

Centralised planning, as suggested by this research, should involve a series of agreements with NGOs to ease information sharing and incorporate them in decision-making. For this to work, SINAPROC has to approach such organisations to understand their motivation and try to align them with the overarching goal of helping disaster victims. That integration can become very complicated, as independence may be the preference of some organisations, but the advantages should be discussed to enhance joint participation.

7.2.4 Assessment of the preparedness model under real circumstances

The ideal way to obtain an evaluation of the model would be to test it in a real situation, which can prove very complicated as disasters are uncertain and cannot be controlled, making the task very unlikely to be accomplished. The next best thing would be to compare it against the real decisions taken by authorities in previous events and contrast results.

In most cases every resource available is deployed to mitigate the impact of the catastrophe, and the urgency of the situation takes precedence over any other activity, especially non-productive actions such as keeping record of everything. Thus, it is very challenging to gather the information required to reconstruct a scenario of the situation lived.

Despite the difficulty, in order to put the system designed to the test, in this research extra data was collected from governmental authorities for the different cases to recreate the decisions taken and assess the results. The purpose of this part is to show the process and result of such task, comparing the results obtained from the preparedness model to the reconstructed scenario of the real decisions.

Information already gathered for each case was supplemented with information about facilities used by authorities, demand per facility, the number of resources deployed and the amount of personnel advocated to each activity. The additional information obtained can be seen on Table 7.5. All of the decisions on the left hand side were provided by authorities.

Table 7.5. Set of decisions of the preparedness model provided by authorities

Decision	Available	Decision	Available
Location of shelters	☑	Allocation of vehicles	
Demand per shelter	☑	Service allocation for distribution	
Location of distribution centres	☑	Relocation of people	
Personnel used for each activity	☑	Allocation of personnel	
Vehicles used	☑	Number of trips required	
Agencies involved	☑	Shipment quantities	
Stock prepositioned	☑	Mode selection	

Missing data is related to the use of the resources. For instance, there is information about the demand per shelter but not about the origin of it; the number of personnel used for each activity but not in what facility it was used. Therefore, the decisions on the right hand side can be optimised to provide the *best possible combination* authorities could have gotten in the real case.

The results from the GIS were disregarded by allowing perfect connectivity, perfect coverage and making available each and every one of the facilities indicated by authorities. The reason is because the model is supposed to provide aid in decision making *before* the disaster situation. Any difference between the flood map and the actual conditions should not affect the activities undertaken in reality.

7.2.4.1 Real case in Veracruz

Data needed to supplement the scenario was required from the nine agencies, with the results shown on Table 7.6. As it can be seen, different agencies contributed with information about their activities, allowing to recreate a scenario of the decisions taken at the time.

Table 7.6. Sources of information about governmental decisions on the flood of 2010 in Veracruz

Decision	Source
Location of shelters	SSV (2014a), SEDENA (2014o) and PCV (2014c)
Demand per shelter	SSV (2014a), SEDENA (2014o) and PCV (2014c)
Location of distribution centres	SEDENA (2014r), DICONSA (2014f), PCV (2014f)
Personnel used for each activity	DIF (2014a), SEDENA (2014q), DICONSA (2014c), PCV (2014d), PCV (2014e), SSV (2014b), IMSS (2014b) and SEGOB (2014g)

Vehicles used	DICONSA (2014d), SEDENA (2014b), SEMAR (2014c), SSV (2014c)
Agencies involved	From all the responses
Stock prepositioned	DICONSA (2014a), SS (2014g) and (2014a)

Figure 7.21 shows how authorities opted for a small number of facilities with high capacity scattered around the region to provide care for the victims. None of the facilities used was in a floodable area, both according to the GIS procedure and the satellite image of the event.

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Figure 7.21. Facilities used for the flood in Veracruz in 2010

The information gathered was included into the model changing the decision variables to parameters. The simplified model was setup to run for 50 iterations of the ε-constraint method and the weighted-sum method, giving the results shown on Table 7.7. The variation of cost between the highest and the lowest value is very small because every decision included in the cost objective function was given by authorities, except for the allocation of distribution. However, changes in the fill rate are considerable.

Table 7.7. Efficient points from the optimisation of the use of resources for the real case in Veracruz in 2010

Cost (MXN)	**Unfulfillment (%)**	**Cost (MXN)**	**Unfulfillment (%)**	**Cost (MXN)**	**Unfulfillment (%)**
6351944	46.89	6466202	33.48	6584504	25.13
6358640	46.07	6476957	32.77	6595247	24.39
6369408	44.73	6487683	32	6606000	23.61
6380162	43.47	6498464	31.24	6616768	22.87
6390868	42.2	6509223	30.47	6627462	22.09
6401641	40.93	6519978	29.73	6638215	21.33
6412417	39.67	6530731	28.96	6649000	20.6
6423173	38.33	6541365	28.2	6659699	19.83

6433790	37.07	6552203	27.43	6670477	19.07
6444575	35.73	6562880	26.67	6676661	18.67
6455418	34.4	6573611	25.92	6680629	18.33

Figure 7.22 displays the comparison of the values above with the Pareto frontier of the model proposed. It seems authorities deployed more resources than needed, at least under the parameters analysed in this research. More importantly, the decisions undertaken could not have reached the desired fill rate of 100%. The result obtained by the *best possible scenario* of the activities performed by authorities is dominated by the Pareto frontier of the system.

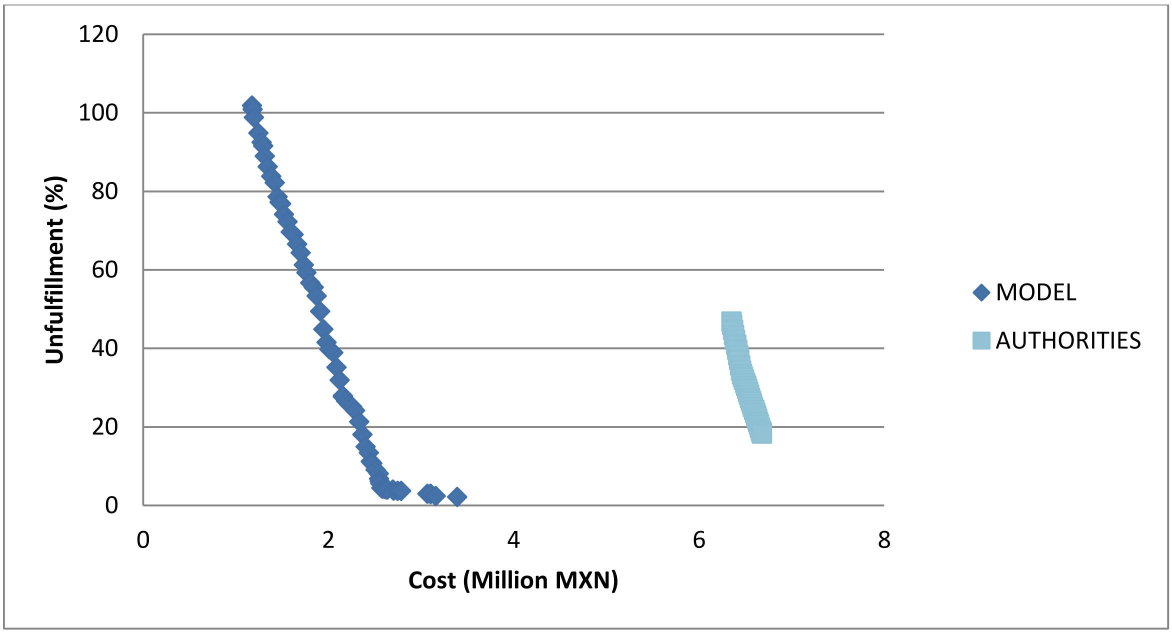

Figure 7.22. Comparison between the real activities performed by authorities and the results from the system for the flood in Veracruz in 2010

7.2.4.2 Real case in Acapulco

Information about decisions made by authorities can be seen in Table 7.8

Table 7.8. Sources of information about governmental decisions on the flood of 2013 in Acapulco

Decision	Source
Location of shelters	SSG (2014a), SSPPC (2014a), SEDENA (2014c) and IMSS (2014b)
Demand per shelter	SSG (2014a), SSPPC (2014a), SEDENA (2014c) and IMSS (2014b)
Location of distribution centres	DIFG (2014a), SSPPC (2014c), (SEDENA, 2014i) and DICONSA (2014c)
Personnel used for each activity	DIFG (2014b), DIFG (2014d), DIFG (2014e), SS (2014b), SSG (2014a), SEDESOL (2014a), SEDESOL (2014c), SSPPC (2014e), SSPPC (2014i), SEDENA (2014e), SEDENA (2014m), SEMAR (2014b), DICONSA (2014d), DICONSA (2014d), IMSS (2014a), SEGOB (2014h)
Vehicles used	SS (2014e), SSG (2014b), SEDESOL (2014b), SEDESOL (2014d), SSPPC (2014f), SSPPC (2014k), SEDENA (2014d), SEDENA (2014n), SEMAR (2014d), DICONSA (2014c), DICONSA (2014c)
Agencies involved	From all the information gathered
Stock prepositioned	DICONSA (2014a), SSG (2014a), IMSS (2014b), SS (2014g)

Figure 7.23 shows shelters (small) and DCs (medium) used by authorities in the flood of Acapulco, both evenly distributed along all of the area. Judging from the satellite image of the situation, there are 6 shelters that seem to be in flooded areas, although the facilities reported by authorities were included in the model with perfect connectivity.

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Figure 7.23. Facilities used for the flood in Acapulco in 2013

The ε-constraint method and the weighted-sum method were applied again for 50 iterations, and Table 7.9 displays the 46 non-dominated solutions obtained. Again a low variation in cost among the solutions can be noticed, but with very high changes in fill rate.

Table 7.9. Efficient points from the optimisation of the use of resources for the real case in Acapulco

Cost (MXN)	Unfulfillment (%)	Cost (MXN)	Unfulfillment (%)	Cost (MXN)	Unfulfillment (%)
12,986,949.89	83.33	13,153,556.36	23.07	13,319,927.74	17.4
12,998,102.28	45.05	13,164,646.9	22.67	13,331,121.45	17.14
13,009,288.57	36.57	13,175,671.76	22.22	13,342,118.14	16.84
13,020,381.6	33.78	13,186,839.8	21.78	13,346,519.64	16.67
13,031,420.72	32.64	13,197,901.53	21.38	13,364,351.36	16.64
13,042,575.38	31.56	13,209,006.54	21.07	13,375,511.16	16.38
13,053,518.17	30.53	13,220,082.77	20.67	13,386,490.4	16.11
13,064,693.73	29.14	13,231,204.08	20.33	13,397,575.26	15.87
13,075,800.69	28.1	13,242,268.65	20	13,408,667.04	15.6
13,086,970.79	27.11	13,253,398.61	19.56	13,419,858.45	15.33
13,098,035.12	26.4	13,264,543.56	19.24	13,430,892.95	15.11
13,109,153.9	25.71	13,275,601.47	18.84	13,441,991.5	14.84
13,120,233.35	24.95	13,286,635.77	18.48	13,453,210.22	14.62
13,131,353.47	24.21	13,297,833.7	18.1	13,464,302	14.33
13,133,466.19	24	13,308,937.58	17.73	13,466,068.01	14.29
13,142,291.71	23.62				

Using the results shown above, a comparison was performed between them and the outcome of the preparedness model, displayed in Figure 7.24. The most service-oriented solution obtained from real activities is around 5% away from the best solution of the model proposed.

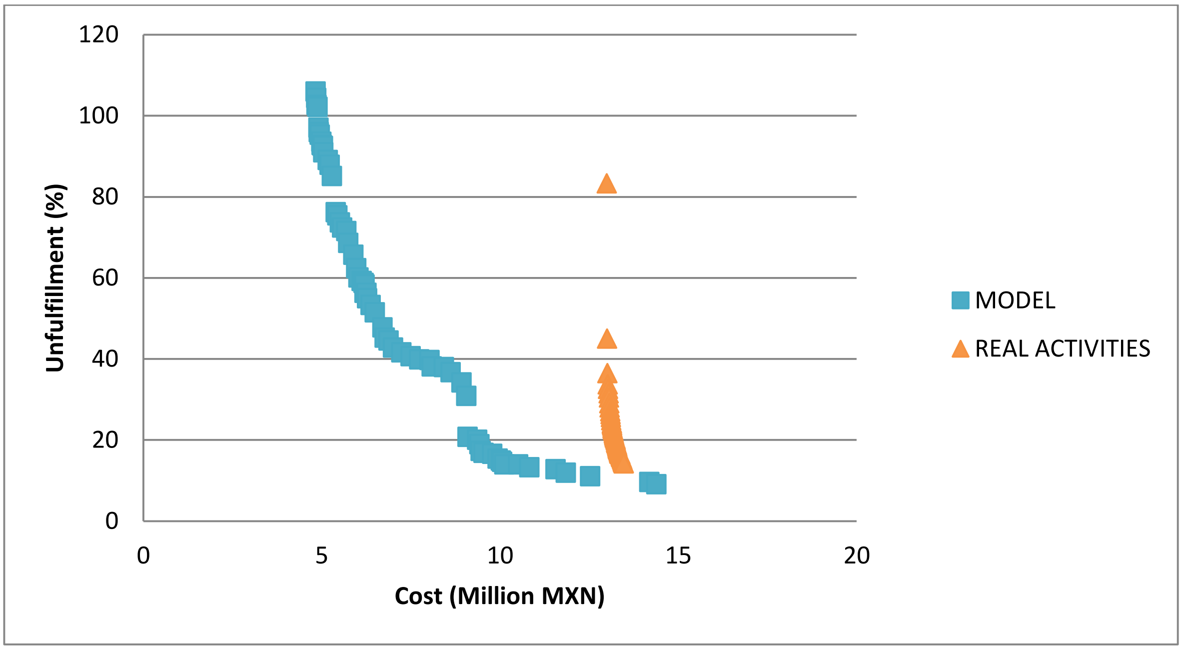

Figure 7.24. Comparison between the real activities performed by authorities and the results from the system for the flood in Acapulco in 2013

7.2.4.3 Real case in Villahermosa

The thirteen agencies were enquired about the decisions taken and resources deployed to alleviate the impact of the disaster in 2007, with the results shown on Table 7.10.

Table 7.10. Sources of information about governmental decisions on the flood of 2007 in Villahermosa

Decision	Source
Location of shelters	PCT (2014a), ISSET (2014b)
Demand per shelter	PCT (2014a), ISSET (2014b)
Location of distribution centres	SEDENA (2014h), SEDENA (2014v), DICONSA (2014d), PCT (2014b)
Personnel used for each activity	ISSET (2014c), DIFT (2014), SST (2014a), SS (2014c), SEDESOL (2014e), SSPT (2014), SEDENA (2014k), SEDENA (2014s), SEDENA (2014w), DICONSA (2014d), IMSS (2014a), SCT (2014), SEGOB (2014g), PCT (2014c), PCT (2014d)
Vehicles used	SST (2014b), SS (2014d), SEDENA (2014s), SEDENA (2014l), DICONSA (2014d), DICONSA (2014d), IMSS (2014a), IMSS (2014a), CENTRO (2014), PCT (2014e)
Agencies involved	From all the information gathered
Stock prepositioned	DICONSA (2013), SS (2014g), SST (2014c)

Facilities used by authorities in the case of Villahermosa are displayed on Figure 7.25. The number of 676 shelters (small circles) is arguably suitable despite the large demand. For instance, police booths were used to shelter people. There are several facilities that overlap with the flood mask provided by authorities, particularly on the southeast, something in line with reports of the flooding (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011).

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Figure 7.25. Facilities used for the flood in Villahermosa in 2007

The information specified above was introduced into the model for real activities. The ε-constraint method and the weighted-sum method were used for 50 iterations each to find solutions. As the number of shelters was very large and the number of medicine kits very low, the Min – Max approach created problems as the level of unfulfillment was extremely high. To aid the procedure, this scenario had the advantage that instead of breaking down the medicine kits from 1 kit of 1,000 people, 100 kits for 100 people were considered. Table 7.11 displays the 17 efficient solutions obtained.

Table 7.11. Efficient points from the optimisation of the use of resources for the real case in Villahermosa in 2007

Cost (MXN)	**Unfulfillment (%)**	**Cost (MXN)**	**Unfulfillment (%)**	**Cost (MXN)**	**Unfulfillment (%)**
87,715,405	50	87,800,672	34.52	87,837,877	33.59
87,727,140	44.44	87,805,440	34.19	87,845,773	33.38
87,750,710	40.74	87,809,053	34.01	87,846,172	33.33
87,770,518	37.30	87,815,717	33.84	88,125,676	32.5
87,782,507	35.56	87,821,803	33.81	88,170,219	32.29
87,793,546	35.14	87,831,158	33.6		

Figure 7.26 shows that the best fill rate obtained from authorities is close to results from the model, but still the solution is dominated by the Pareto frontier. For the same cost a better solution in terms of fill rate can be obtained with the proposed system and vice versa.

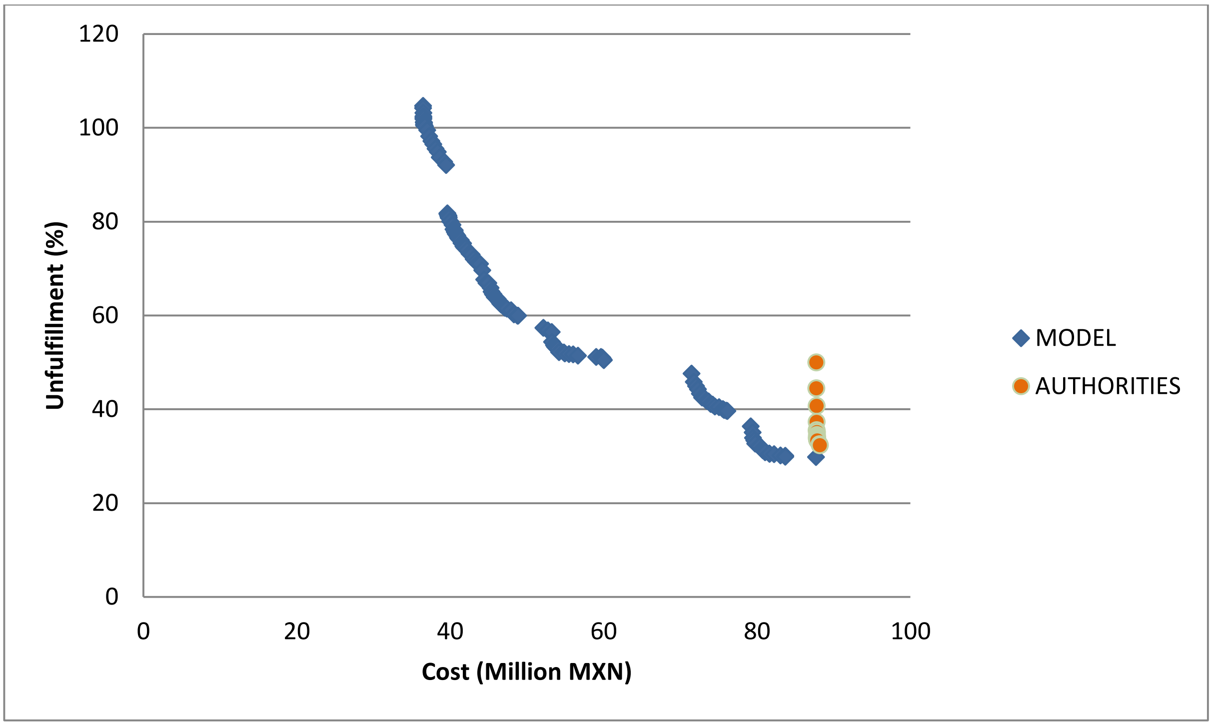

Figure 7.26. Comparison between the real activities performed by authorities and the results from the system for the flood in Villahermosa in 2007

7.2.5 Summary and discussion

The purpose of the preparedness model is to provide support to plan the activities required to minimise the impact of the flood on vulnerable people. In this section, different tests have been performed to evaluate the performance of the model under different circumstances.

Firstly, an analysis focused on the results of the geographical procedure was undertaken, aiming to understand both the advantages and disadvantages of the use of the GIS procedure. According to the results, the use of GIS can provide solutions that reduce risk. For the small and medium cases the potential improvements were very limited, concluding that the use of the GIS is not worsening the solutions considerably, but it takes away part of the risk. For the large-scale case, although potential benefits increased, also did risk in a higher rate. The elevated risk associated with disregarding the GIS suggested that still in that situation the use of the geographical analysis can be worth it. For the three cases, even taking the difference between the flood map developed and reality, still potential benefits seem outweighed by risk.

For the preparedness model three different analyses were performed; the first one comparing the results from the integrated model against the combination of a location and an allocation model; afterwards a comparison from agencies working independently against a coordinated approach, and finally the contrast of the outcome of the system and the best possible scenario of the activities performed by authorities.

Thinking about the structure of the model, it is possible for someone to weight the possibility of having two different sets of decisions: location and allocation activities. From the results in cases with shortage of resources, the sequential combination of models provided acceptable results, whereas for the case with excess of resources this approach can waste many resources. The sequential combination of models ends-up being more service-oriented than cost effective. The reason is that although cost is optimised in the location model, the allocation model is based on fill rate and it seeks to maximise that performance measure within the context provided by the first model. Overall, the use of the sequential approach provides less flexibility than the model proposed and provides lower-quality solutions.

Putting on the same conditions a scenario with the joint approach proposed by this research and an independent perspective, results showed that absence of coordination can lead to poor level of service even when the overall resources are enough for the situation. The negative impact of the absence of coordination increases with the level of damage caused by the disaster. Results showed that there is no agency in Mexico capable of dealing with a disaster on their own, the need of interoperability to delegate and distribute tasks among different actors, and the potential to provide better results in both cost and service by adopting a more systemic approach. The value of the results is linked to opposing analytically the common underlying assumption on most of the models in the literature considering only one actor.

The value of this comparison goes beyond just a theoretical proof of the unsuitability of an independent approach, but to highlight that is a problem that can affect any organisation. There is evidence in Mexico of events where civil organisations took part by themselves (Hernández, 2009). Moreover, from reports obtained by this research there is hardly any evidence of the involvement of organisations other than Red Cross for disaster preparedness. Let us extrapolate the same idea of independent decision-making to NGOs or civil organisations, because that may as well be the situation on different disasters in the country. The involvement of NGOs can be complicated from a political point of view, but the advantages from the perspective of disaster victims are very attractive. The integration of these organisations could work as pairs of governmental authorities, being involved when the situation requires it for them to use their resources in a more effective matter and for the government to take advantage of the resources made available by them. How different could have it been if these organisations would have been involved facilitating relief for the shortages in Acapulco or aiding shelter management in Villahermosa? Answering that question is well beyond the scope of this work, but given the results shown here it is important to start asking that kind of questions for future research.

The major test for the model was the comparison to the decisions actually undertaken by authorities. The results obtained represent of the *best possible scenario* under the decisions taken by authorities. For this, only allocation was optimised and the rest of the decisions were input as authorities decided. In this work it is considered as an upper-bound in order to compare the results of the model against the assumption of an ideal of the real management.

Overall, in the three cases too many organisations were deployed. The considerable use of resources from authorities can be viewed from a good and bad perspective; ranging from a service-oriented mentality of the decision-maker to simply poor decision-making. Focusing on the former for the sake of the argument, Table 7.12 displays the most service-oriented solution from the activities performed by authorities in Veracruz (REAL) contrasted against four outcomes: the aggregated result from independent agencies (AGENCIES), highest fill rate from the sequential combination (L-ALOC), the most service-oriented solution of the preparedness model (MFR) and the point chosen as input for the response model by the author of this work (V1ND59). The purpose of this part is to compare the performance of these solutions not only in terms of the two performance measures selected, but from the perspective of some of the most common metrics in the literature. The results show that the number of facilities, particularly DCs, seems unnecessary.

The solution of real activities seems to have good results in terms of evacuation distance compared to the rest, showing a possible emphasis on this activity. The aggregated result of the agencies should be considered carefully, because the scenario was created with the combination of the highest-fill rate solutions of each agency, allowing people to go to their nearest shelter. Very poor product fill rate is due to relief being sent at wrong shelters. As there is no coordination, every agency had an expected demand per shelter, but as people decided where to go based on distance there was oversupply in some shelters and undersupply in others. Also, there was low average occupancy rate. These results point towards a need to assess the number of medicine kits available for the region in the case of disaster, being the only resource with shortages under ‘small scale’ circumstances.

Table 7.12. Comparison of preparedness results for the case of Veracruz-Boca del Río

Solution	Cost (MXN)	Ag	Fill Rate (%)				Facilities		Total Trips	Shelters	Evac
			Food	Med	NVH	NVS	Shel	DCs		Occupancy avg (%)	Distance p/person (miles)
V1ND59	2,698,715	6	100	81.71	100	96.85	6	2	7	90.93	3.81
MFR	3,389,298	6	98.29	81.71	100	100	6	1	6	73.85	3.76
REAL	6,896,400	9	100	77.72	100	56.61	9	6	18	88.12	3.32
L-ALOC	6,038,170	9	100	79.69	100	96.46	15	2	68	100.00	4.39
AGENCIES	8,092,768	9	42.45	27.87	98.62	91.09	37	1	42	38	2.18

Overall, it can be seen that the model yielded better solutions in most of the metrics. The system designed provided the chance to select a solution that reduces cost considerably whilst maintaining good level of service, high occupancy, low number of organisations, few facilities, and relatively acceptable evacuation distance per person.

Table 7.13 shows a similar comparison to the above for the case in Acapulco. The same trend about cost and number of organisation remains, showing that the use and management of organisations was not justified. Conversely, the number of facilities used in reality seems sensible with a high occupancy rate and low evacuation distance per person. The combination of models in this case performed very well, with comparable metrics to the maximum service level obtained by the model, but still outweighed by the solution chosen from the Pareto frontier.

Table 7.13. Comparison of preparedness results for the case of Acapulco

Solution	Cost (MXN)	Ag	Fill Rate (%)				Facilities		Total trips	Shelters	Evac
			Food	Med	NVH	NVS	Shel	DCs		Occupancy avg (%)	Distance p/person (miles)
A1ND54	10,061,802	6	76.13	33.40	99.94	99.98	42	6	46	91.30	10.03
MFR	14,379,448	9	76.56	34.41	99.92	99.96	83	10	101	57.67	9.95
REAL	13,542,000	10	71.36	26.05	100	98.95	56	5	110	84.78	8.50
L-ALOC	11,596,961	10	71.37	33.31	100	100	46	1	65	100	9.22
AGENCIES	15,896,167	10	69.99	19.25	66.98	97.02	97	3	28	59.65	5.25

The aggregated solution from the agencies delivered the highest cost and lower fill rates in general. In this case, those fill rates were because of absence for distribution personnel in agencies with medical supplies, given that not many resources were wasted for sending relief to the wrong shelters. The benchmark of evacuation distance from the agencies is important to consider, being significantly lower than the rest. The large value of evacuation distance per person in most of the solutions in this particular case is linked to the extension of the city, with mountains in the middle and a linear distribution.

Finally, the same analysis was performed on the city of Villahermosa to compare and contrast the different solutions, as shown by Table 7.14. Up to this point authorities seemed to have most of the resources required disaster management at disposal; however Villahermosa was an exceptional case. Something worth noticing is how when National agencies deploy all of their resources, the situation can be managed by less organisations. The number of facilities was a problem in reality; having more than three times the number of shelters actually needed created complications such as complex distribution. The high number of shelters required overall combined with the unavailability of resources created several cases where the total number of trips was actually lower than the number of shelters opened.

Table 7.14. Comparison of preparedness results for the case of Villahermosa

Solution	Cost (MXN)	Ag	Fill Rate (%)				Facilities		Total Trips	Shelters	Evac
			Food	Med	NVH	NVS	Shel	DCs		Occupancy avg (%)	Distance p/person (miles)
T2N138	80,643,186	4	10.06	2.02	99.94	99.67	152	8	117	96	5.88
MFR	87,674,404	12	10.10	2.87	99.73	99.28	202	14	231	91.28	6.07
REAL	88,265,000	13	8.41	2.61	99.56	98.07	613	9	583	100	6.13
L-ALOC	87,817,000	13	10.10	0.12	100	100	214	2	217	100	5.45
AGENCIES	91,954,147	13	10.06	1.77	98.83	97.31	282	3	70	93.21	3.18

The performance of the aggregated scenario from the agencies is very respectable for this case, with shortages of medicines again for the absence of personnel for distribution of medicine kits. This comparison also shows the minimum distance being two miles below the rest, but at the highest cost possible. This is the only case where the evacuation distance of the real activities is higher than the rest, which can be explained by the chaotic circumstances and the high number of facilities, obscuring any evacuation plan designed. The fill rate is extremely low, which points towards the need to evaluate prepositioning policies, always watchful of the outstanding conditions of this event. Overall, it can be seen that the solution chosen provided very good metrics in comparison to the rest; particularly saving on cost, number of organisations and number of facilities.

The point of these comparisons was to give context to the solutions obtained, but also to analyse further the results in terms of different metrics considered in disaster management. The model provided solutions aligned to expectations, using resources in a very adequate manner and providing flexibility. In general, there seems to be an oversupply of human resources; i.e. the number of organisations and people involved is larger than the actual requirements. Also, the model showed the possibility of performing scenario planning so authorities can plan in advance under what situations national authorities should take part, and under which conditions only local and regional authorities ought to be involved.

Talking about shortcomings, even though results from the evacuation distance were somehow close to the benchmark of real decisions and combined models, it is still a very important concern. Decision makers should be aware of the importance of a well-design evacuation plan to supplement this model. Also, as the model is designed it is not able to handle differences in hierarchy between organisations. This shortcoming can be addressed by manually incorporating agencies from the same or adjacent classes on scenario analysis to identify when the barrier is breached, but the use of hierarchical models look like a promising venue.

It is important to mention the non-convex areas present in the Pareto frontiers obtained for the cases of Acapulco and Villahermosa. The activation/deactivation of an agency involves the inclusion/exclusion of every resource available for the organisation, making it possible to have very small improvements in fill rate until another agency is deemed necessary, thereby increasing considerably the level of service from one point to the next. That can lead to very pronounced steps in cases of few agencies with noticeable differences in terms of resources.

Overall, the results of the preparedness model display potential to improve operations and aid decision-making over current tools used from authorities, and the model showed an adequate behaviour under different circumstances and geographical areas in Mexico.

7.3 Assessment of the response model

The results obtained of the application of the response model for each one of the case studies are included on Chapter 6. To further assess the model, the analysis performed was twofold: considering independent participation from the organisations and reconstructing the decisions taken by Mexican authorities.

7.3.1 Value of the multi-organisational perspective

Given the assumptions underlying most of the articles in the literature of humanitarian logistics, to apply current models either resources from different actors need to be aggregated together leaving allocation decisions for other decision processes, or each actor should run an independent model and act based on that.

Independent response posed some challenges in terms of comparison, thus the same baseline was considered for the scenarios with and without coordination. The reason is twofold: only the performance of response operations is considered here, and the fact that the preparedness model delivers a set of efficient points as solution. For the former by using the same data as input, a potential bullwhip effect is avoided.

For the comparison a variable was included allowing agencies to shut down DCs based on employees available and individual agencies are assumed to operate throughout all periods.

The biggest constraint for comparison was given in terms of the threshold introduced to seek equity. Assuming that a single agency can comply with that constraint proved unrealistic, creating unfeasibility in most of the cases. Therefore, the threshold constraint was invalidated for the agencies. In that sense, disregarding that constraint provided an unfair advantage for the performance of some agencies over the results from the response model in Acapulco and Veracruz, creating the need to run an alternative scenario for these cases relaxing the same constraint for the sake of comparison.

Under the assumptions aforementioned and including the idea that agencies would focus on reaching the highest service level possible, the model was used to obtain a value for each one of the agencies involved on each one of the cases. The reason the entire Pareto frontier was not constructed for each organisation is because several organisations did not count with resources to supply after initial conditions, yielding small to null changes in cost.

Figure 7.27 displays the comparison between the Pareto frontier obtained by the response model for Veracruz, the model relaxing the threshold constraint and the most service-oriented solution for each one of the agencies. The effect of the threshold constraint can be slightly appreciated on cost-effective solutions compared to the original model. Most of the agencies are delivering very poor solutions on this case, because when leftover resources from preparedness are depleted most of the agencies do not count with any more relief items. On the other hand, FONDEN lacks of human resources for healthcare and distribution.

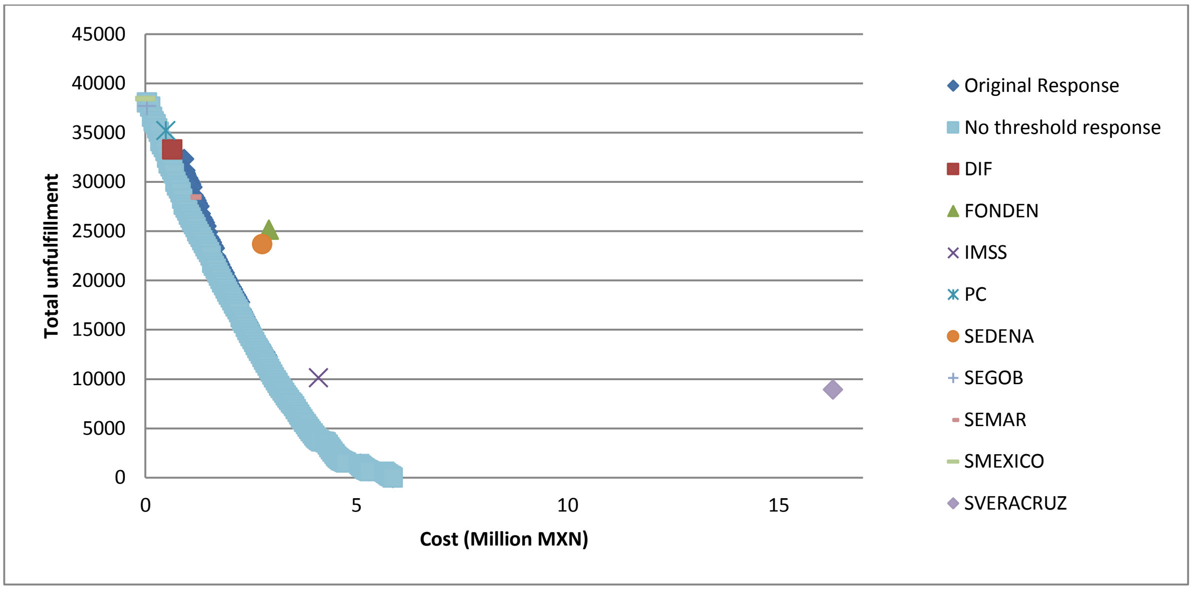

Figure 7.27. Comparison of the results for individual agencies for the case of Veracruz

The overall message from the above figure is that coordination is of paramount importance for response as the inclusion of time elucidated further the limitations of each organisation.

Figure 7.28 provides a similar comparison for the case of Acapulco, where the difference caused by the threshold constraint has a more noticeable impact. The limitations of every agency are highlighted, far away from the complete fill rate attained by the coordinated approach. Evidently, agencies are not able to cope with the situation appropriately on their own, especially when several periods of time are involved.

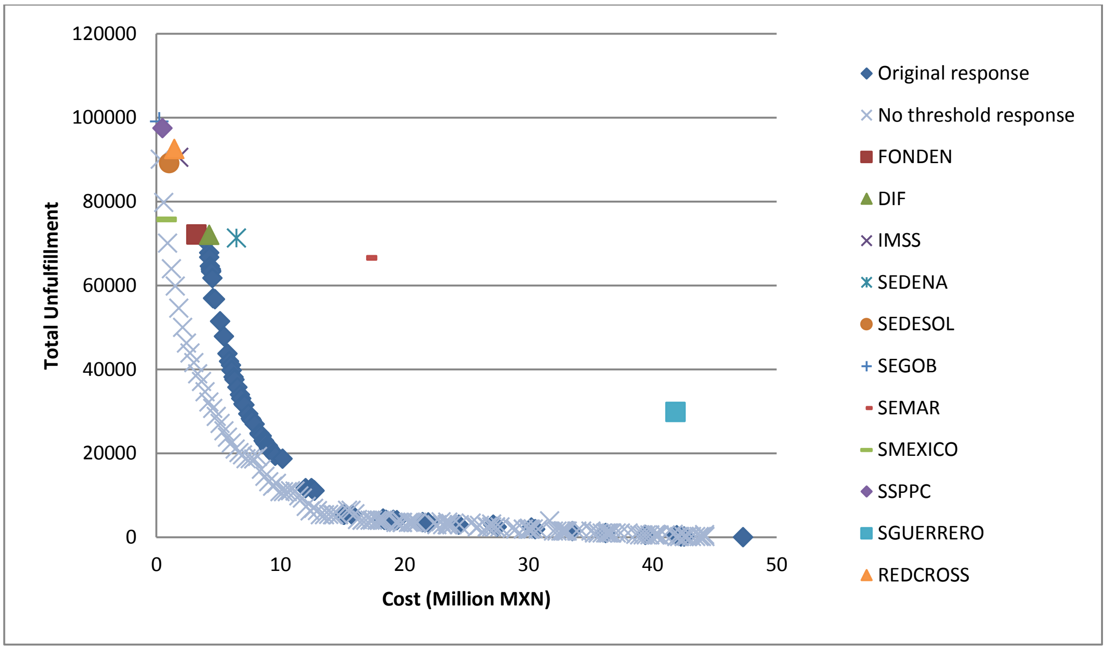

Figure 7.28. Comparison of the results for individual agencies for the case of Acapulco

A more challenging situation is presented in the case of Villahermosa, as shown by Figure 7.29. The magnitude of the case is originating extremely poor performance of every agency, with most of them providing very low levels of fill rate. SMEXICO and SEDENA deployed most of their resources, but they are still far away from the possibility of attaining good fill rates. Even though Red Cross displays a better performance than half the agencies, the results indicate that without proper coordination none of the organisations other than governmental agencies can have a significant impact in the system. This result points out to the fact that having several organisations working on their own cannot yield appropriate disaster management, especially for a large-scale disaster.

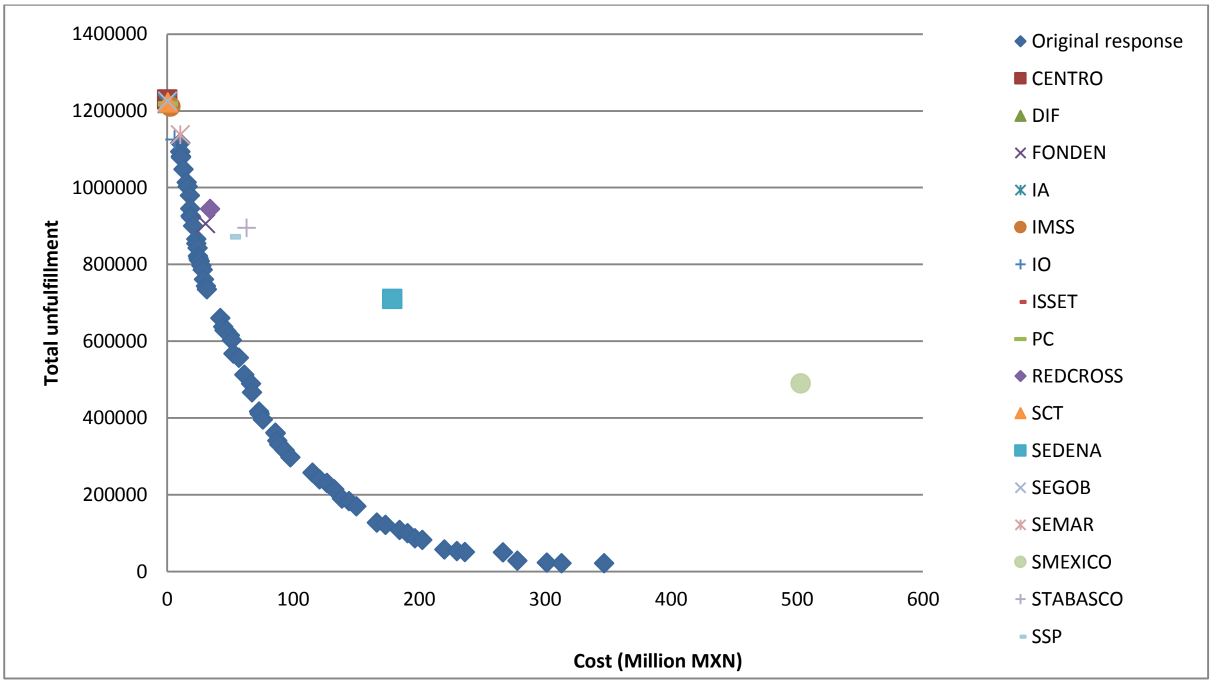

Figure 7.29. Comparison of the results for individual agencies for the case of Villahermosa

According to the results, current models neglecting the interdependency between organisations can be suggesting sub-optimal solutions overall, therefore affecting the protection provided to disaster victims. The acknowledgement of the importance of coordination is one of the outcomes obtained from this analysis.

7.3.2 Assessment of the response model under real circumstances

A scenario emulating the decisions taken by authorities was constructed by requesting information from each one of the organisations involved, along with governmental reports. As some data was unavailable per period, the information used for the preparedness model under real circumstances was assumed constant for every scenario.

Data about the number of non-medical items delivered per period per city was provided by the Ministry of Interior SEGOB (2014f), whilst the number of medicine kits distributed per day was provided by SEGOB (2014c). All of the information was corroborated with data from FONDEN (2010), FONDEN (2013) and FONDEN (2007) for Veracruz, Acapulco and Villahermosa, respectively.

Mentioning some of the considerations required, perfect coverage and connectivity were considered. Demand per period was a major drawback because there was data about demand changes from one agency on the three cases but not from the rest. Therefore, the same trends obtained on Sections 6.1.4.1, 6.2.4.1 and 6.3.4.1 were applied for shelters used in reality for the cases in Veracruz, Acapulco and Villahermosa, respectively. The ideal points for the individual minimisation of both performance measures are shown on Table 7.15, with small changes in cost because the only term in cost being optimised was transportation. A focus on victims is assumed and the solution with the highest fill rate is used for the analysis.

Table 7.15. Ideal points for each one of the response cases under real circumstances in Villahermosa

Objective	Veracruz		Acapulco		Villahermosa	
	Cost (MXN)	Total unfulfillment	Cost (MXN)	Total unfulfillment	Cost (MXN)	Total unfulfillment
Min cost	81,552,000	38,570	114,350,000	101,990	833,240,000	1,151,700
Min unfulfillment	81,575,576	4,490	114,530,000	5,800	866,682,282	44,580

The model was run for the case of Veracruz to provide the solution displayed on Figure 7.30 in comparison to the Pareto frontier obtained by this research. There is a significant overflow of resources, leading to a significant difference in terms of cost. The reader could be concerned about a considerable overestimation of cost given the uncertainty about the activation/deactivation of agencies and the assumption of complete presence. Even though wage cost is clearly important, the cost of total activation for this case is 25,854,948 MXN, which means less than a third of the result obtained. The real driver of cost in this case was the amount of relief sent to the area, representing nearly 70% of the overall expenditure and provided by the reports of relief authorised. On the other hand, according to the reports real activities could not reach the level of service provided by the model. The reason is because authorities did not report the delivery of the products composing the hygiene kit included in Mexican regulations. Besides, five medicine kits on early stages could not have been fulfilled.

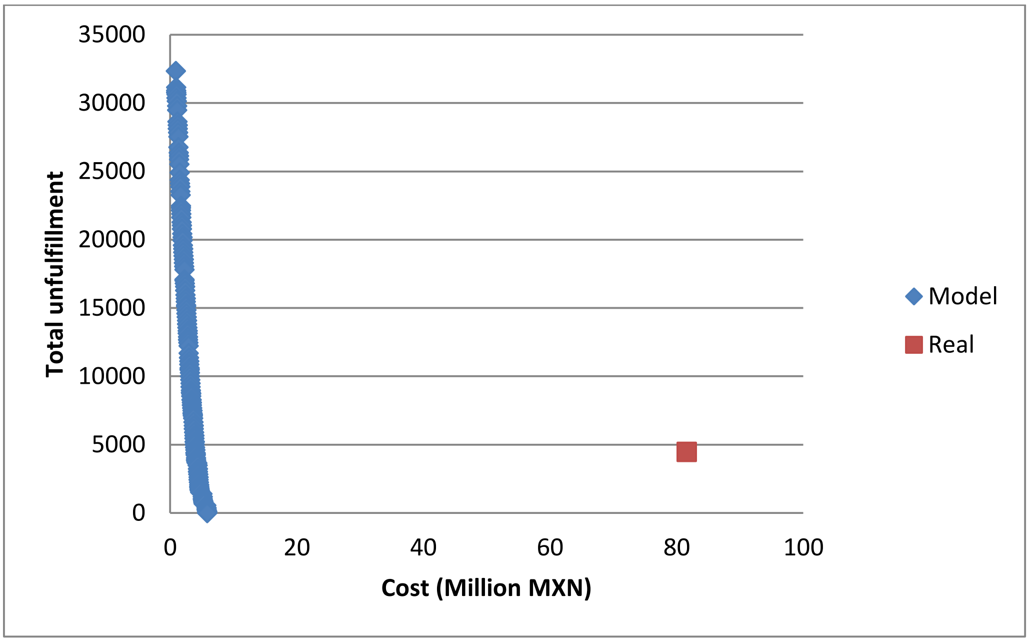

Figure 7.30. Comparison of the real response activities with the Pareto frontier of the response model for the case of Veracruz

Figure 7.31 displays the outcome of the information about real response activities performed by authorities in Acapulco contrasted with the Pareto frontier obtained in this research. In this case procurement cost was around 34% of the overall cost, being surpassed by the cost of personnel. However, only with the cost of the relief items sent to the area in reality the Pareto frontier is able to provide a better fill rate than the one obtained by this case.

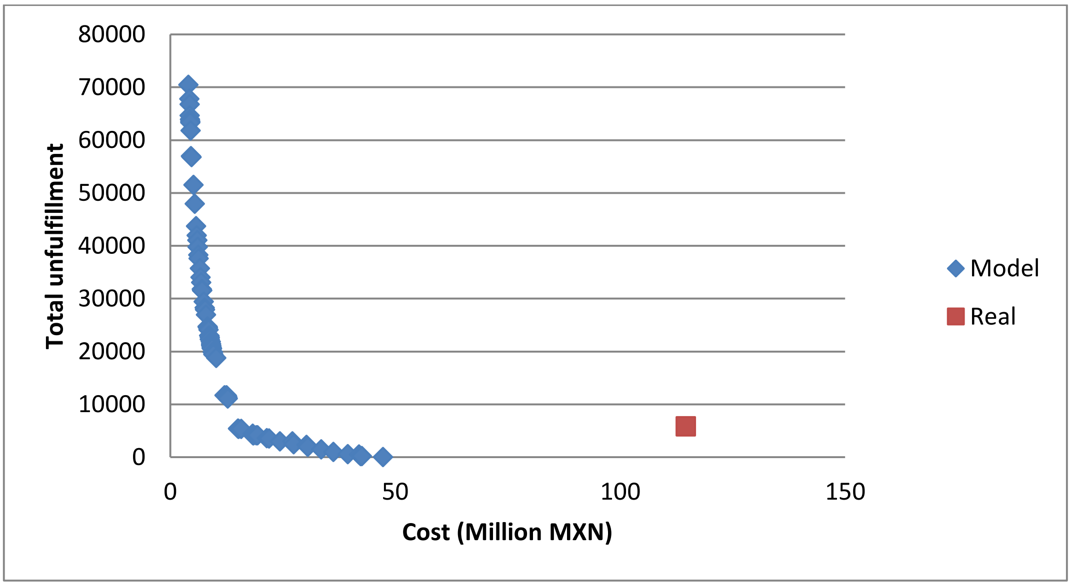

Figure 7.31. Comparison of the real response activities with the Pareto frontier of the response model for the case of Acapulco

Not enough of the products required by the hygiene kit were introduced, or more importantly this was done only once. For instance, combining all the diapers distributed, the result is the provision of one diaper per day for the 3.75% of the total number of people, away of the estimate of 5.5% of children under 2 years INEGI (2010a). On the other hand, there seems to be an oversupply of items such as food pantries, cleaning kits and personal kits.

Figure 7.32 introduces the results of the comparison between the outcome of the response model and the maximum fill rate attained by the scenario resembling decisions from Mexican authorities in Villahermosa. Personal kits dominate the shortage of products, which is mostly related to relief being sent below requirements or out of time. For instance, delayed delivery of medicines affected demand over the first three periods; reason why demand for medicine kits was pushed until the delivery from authorities reached the region.

Procurement cost was around 267,430,471.90 MXN, to which adding just one period of involvement of all of the and disregarding the cost of distribution, yields a total of 318,418,250.01 MXN spent. That expenditure would be higher than 313,112,120.91 MXN, which is one of the efficient points of the Pareto frontier with a value of unfulfillment of 22,185. This value is well below the achieved value of 44,580 with decisions taken in reality, and thereby there is certainty that the *best case* of the actions performed by authorities is dominated by the Pareto frontier of the system proposed.

Overall, for the three cases there is evidence of oversupply of some products, inconsistent use of resources from one situation to another as exemplified by the delivery of hygiene kits on every region, extreme expenditure in relief items, and the opportunity to improve disaster operations by using the response model proposed.

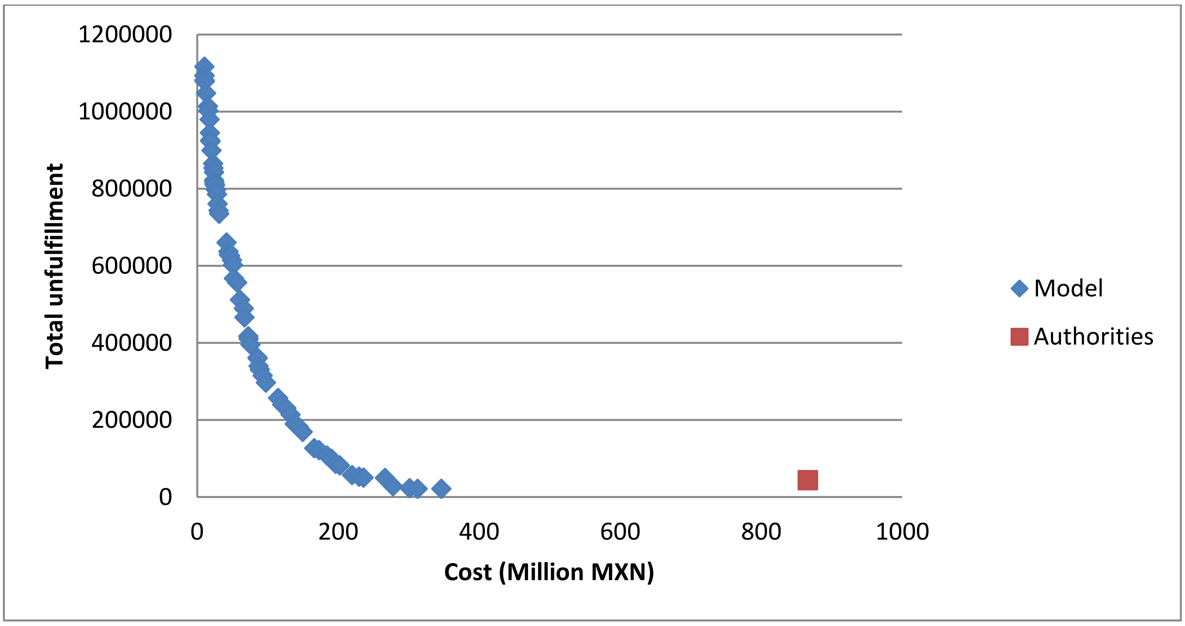

Figure 7.32. Comparison of the real response activities with the Pareto frontier of the response model for the case of Villahermosa

7.3.3 Summary and discussion

The response model was designed seeking to balance use of resources and level of service. In this part two tests were executed: a comparison between an independent and a coordinated approach, and a comparison of the results of the models to the real activities

In line with expectations, the coordinated approach yielded better results than independent efforts from every agency. The relevance of these results is linked to the case in Villahermosa where Red Cross, NGOs and other civil organisations were included in the analysis. Beyond the evident conclusion that none of them can provide as much support as Mexican authorities, there is a lesson about the importance to integrate them in disaster response decisions. Overlooking some or all of these organisations is hindering the potential to perform successful disaster management operations.

Assuming coordination between most of the organisations participating in disaster management, the second analysis performed was incorporating real decisions taken by authorities for the three cases examined in this research. Even though information limitations are acknowledged, the results still have some valuable insights. Just considering the expenditure in supply products sent to each one of the regions along with wages of only one period, none of the fill rates obtained by authorities can reach the level of service that can be delivered by the model. This has two implications: the response model is providing a suitable alternative to be considered by authorities and decisions taken on the preparedness stage can greatly affect the results of the system. Elaborating on the latter, facilities selected on the preparedness phase affect demand distribution and logistical operations, producing a ripple effect that affects response. For example, having 613 facilities in Villahermosa for the case of the flood in 2007 translated into complicated logistical activities.

For the case of Veracruz, Table 7.16 displays a comparison of four different solutions: the maximum level of service from independent agencies (Agencies), the maximum level of service from real activities (Real), the maximum level of service from the response model (MFR) and the solution chosen by the author of this work operating as decision-maker. For the independent agencies, variables obtained as outcome from each one of the organisations were aggregated into a single scenario.

Table 7.16. Comparison of solutions for the response case in Veracruz-Boca del Río

Sol	Cost (MXN)	Max agencies p/period	Fill rate (%)							Max personnel used p/period		Max vehicles p/period	Total trips
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health		
R1V114	4,259,706	5	100	100	100	100	100	75.14	100	348	17	7	15
MFR	5,864,065	5	100	100	100	100	100	100	100	388	17	4	9
Agencies	54,170,350	9	85.07	100	84.42	84.42	84.42	100	100	2159	33	4	128
Real	81,575,576	9	100	81.06	100	100	0	100	83.31	621	502	24	336

Even though independent agencies have together the same resources as the ones used by the coordinated approach, the combination of their activities is considerably more expensive and reaching less people, due to duplication of efforts. Activities performed by authorities reach good fill rates, except for the problems with the hygiene kits and medicines mentioned earlier, supplemented by absence of enough personnel for shelter operations. A very clear sign of the redundancy on the last two scenarios is provided by the need of only five agencies to provide products and services required, well below the nine agencies involved.

In general, results from authorities show deficient allocation of resources and considerable lead time for medicines, pointing towards severe complications in needs assessment. Therefore, room for improvement is noticeable; either from the solution proposed or the one with maximum fill rate provided by the system.

For the case of Acapulco, Table 7.17 displays a similar comparison of results. The performance of the aggregated accomplishments of all agencies yields fill rates above 90%. However, the duplication of efforts and oversupply of some resources caused the cost to be more than three times the selected option, requiring more people as well. The maximum number of agencies required per period is considerably lower for both of the results of the model, exhibiting an inefficient use of resources in reality. It is noteworthy that the improvement in less than 10% of coverage of healthcare has an impact of over 21 million MXN. The reason is because although the maximum number of healthcare personnel is the same, at some period the system used that number of people for high-demand periods, deactivating the largest healthcare agency (SMEXICO) and balancing with SGUERRERO and IMSS for the rest of the periods with lower demand.

Table 7.17. Comparison of solutions for the response case in Acapulco

Sol	Cost(MXN)	Max agencies p/period	Fill Rate (%)							Max personnel used per period		Max vehicles per period	Total trips
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health		
R1A46	25,461,547	7	100	100	100	100	100	90.05	100	1534	127	73	122
MFR	46,725,583	5	100	100	100	100	100	100	100	1215	127	26	221
Agencies	78,525,770	11	93.42	97.53	92.34	92.33	92.33	100	100	3407	149	4	88
Real	114,750,000	11	100	100	100	100	43.59	100	100	3803	137	73	924

In general, the *best possible outcome* from decisions taken by authorities has a good fill rate, although with excessive use of resources as revealed by the valuation in cost.

The last comparison was performed with the results for the flood in Villahermosa on Table 7.18. In this case there are not enough resources to fulfil demand, something resented by the solutions from independent agencies and real activities where redundancy and inefficiency take place.

Less than a third of all of the agencies used was actually required in the critical stages. That stresses the fact that optimising disaster operations involves also optimising the agents involved and not only the resources gathered. Also, the use of 613 shelters can increase considerably the number of trips required, thereby adding complexity to response operations.

Table 7.18. Comparison of solutions for the response case in Villahermosa

Sol	Cost	Max agencies p/period	Fill Rate (%)							Max personnel used p/period		Max vehicles p/period	Total trips
			Food	Med	CKIT	PKIT	HKIT	NVH	NVS	Op	Health		
T2ND66	301,472,965	5	100	78.61	71.35	74.91	100	100	99.98	16886	2796	203	705
MFR	346,809,890	7	100	79.47	80.09	75.26	100	100	100	14754	2790	234	3099
Agencies	881,796,124	16	90.48	77.21	63.91	67.33	84.72	99.89	100	16668	1524	40	4080
Real	1,104,752,282	16	95.76	58.13	71.11	65.28	87.93	100	100	40302	3166	259	13830

Overall, the lack of resources derived in poor fill rates for the real set of decisions and independent agencies as duplication of efforts and challenges in resource management affected the performance of these solutions. The real case incurred in oversupply of some products and undersupply of others. Providing a certain amount of products out of time is the same as not supplying them. Conversely, there was an oversupply of food at the middle and all the way until the end of the inundation.

The *best possible set of decisions* taken by authorities has the potential to provide a good level of service. The results point out to a focus on people and availability of resources, even to the point of an excess of them. It seems that for the Mexican case the problem is not mainly resource availability, but the way these resources are used in practice.

7.4 Chapter Summary

Overall this chapter introduced an evaluation of the system proposed in this research. The results from the geographical procedure were assessed considering real images to identify the level of accuracy obtained. The importance of integrating GIS in decision making for disaster management was stressed by contrasting a scenario with and without GIS, demonstrating the increase in overall risk of disregarding the GIS outweighed potential benefits. Also, both models were assessed using a set of benchmarks. The preparedness model showed consistent improvements for the three cases compared to a combination of a location and an allocation model, independent dcision-making and the activities performed in reality by authorities. Similarly, the response model used the last two benchmarks aforementioned maintaining positive results across cases.

The next chapter undertakes the discussion about the overall results of the research developed, including the contribution of the work performed and future research from the perspective of this dissertation.

8 CONCLUSIONS AND FUTURE WORK

Research is "*an original contribution to the existing stock of knowledge making for its advancement*" Kothari (2004). The word comprises a vast meaning along with a large number of activities requiring rigour in order to provide reliable results.

This dissertation was developed based on the principles of research, seeking to provide both a novel perspective by including a multi-organisational approach for disaster preparedness and response, and an innovative tool for the improvement of disaster operations. This chapter elaborates on the value of the work undertaken, the answer to the research questions raised and the basis left by this dissertation for future contributions to the area.

8.1 Research questions review

The purpose of this research was to *develop a system for disaster management based on a combination of optimisation techniques and GIS to aid multi-organisational decision-making regarding the location of shelters and distribution centres, the amount of prepositioned stock of relief items, the allocation of material and human resources, and relief distribution for floods in Mexico.* A system fitting this description was developed, as described in Chapter 5. A set of research questions were raised. This section focuses on discussing the results obtained from the work in terms of these questions.

8.1.1 RQ1: Is the system proposed adequate to aid decision-making on floods in different regions in Mexico?

Considering the need to advance research on disaster management for developing countries (Altay and Green, 2006, White et al., 2011) and the absence of papers investigating catastrophic floods in these countries (Patel and Srivastava, 2013), this research introduced a robust system applicable under different circumstances for floods in Mexico.

Three case studies in different areas of the country were studied; each one with distinctive characteristics, magnitude, origin and duration. Each one of the cases was tested under different scenarios to get a clearer picture about the performance of the system designed. Chapter 6 introduced the application procedure and a discussion about the results obtained.

The use of GIS tested the possibility of eliminating facilities in floodable areas for the three regions. The outcome showed good results across cases, although a more consistent performance was obtained in flat lands. This was supported on Chapter 7 after a comparison to images of the real flood and/or flood representations from authorities.

Elaborating on the functionality of the preparedness model, the application for each scenario exhibited adequate conflict between cost and fill rate, appropriate optimisation of organisations involved and a successful measure of equity among shelters in terms of fill rate. On the other hand, the response model displayed also a good range of conflict between objectives, positive effect of the equity constraint for small and medium cases, and adequate optimisation of organisations involved for different periods of time.

Overall, the three components delivered set of coherent and consistent results for the three case studies. The behaviour of the models kept in line with the rationale of design across cases, showing the capability of the system to handle different settings. Improvements in several metrics compared to different benchmarks on the three regions of Mexico were obtained, proving the suitability of the system proposed to different regions in the country.

8.1.2 RQ2: How does the use of geographical analysis affect the policy applied for disaster management?

Despite of ongoing recent developments in the use of GIS for disaster management (e.g. Feng and Wang, 2011, Wang et al., 2013, Kaiser et al., 2003), the common trend in humanitarian logistics is to employ these systems for data visualisation and network analysis rather than emergency analysis (Lee et al., 2011). Considering the potential of these tools to support other activities (Cova, 1999), it was important to investigate the value of embedding GIS in a disaster management system to draw conclusions based on empirical results. This type of test has not been undertaken before in the literature and it can deliver interesting insights about the incorporation of GIS for future analytical tools for flood management.

An experiment for the three cases under real circumstances was set-up to address this question. The instance considered scenarios with and without the use of GIS. The purpose was to identify potential benefits and drawbacks generated by the use of these systems.

For the cases of Acapulco and Veracruz, potential improvements of not using the GIS on the performance measures were minimal. Additionally, a large number of solutions include floodable facilities, potentially affecting hundreds of people. The case of Villahermosa showed the most significant advantages in terms of cost and fill rate of ignoring the GIS system. Nevertheless, the number of people endangered was in average a third of the total number of victims. Therefore the potential benefits of dismissing the system are surpassed by the risks implied in doing so. It is important to mention that putting people on a floodable facility duplicates cost as more facilities have to be opened, requires relocation, creates delays in relief aid delivery, and carries the possibility of having to improvise facilities or leaving people without protection.

Overall, GIS can reduce risk for disaster victims, potentially making a significant positive difference in disaster management. According to the results obtained, the risk of disregarding the GIS can be far beyond the expected benefits.

8.1.3 RQ3: Is there a difference for disaster preparedness and response between having coordinated agencies and independent agencies?

One of the gaps identified on Chapter 3 is related to the assumption of a unique decision maker for disaster management. In order to use most of the models available currently, an individual organisation has to take independent decisions or aggregate its resources with other organisations. This research investigated the difference between a coordinated and an independent approach using empirical data. The reason was because of the assumptions underlying most models in the literature, reports of civil organisations participating their own (Hernández, 2009), and evidence of difficulties sharing resources among agencies. For instance, authorities reported a situation where relief products were actually available but DIF did not have vehicles at disposal, requesting help to other agencies and ultimately hiring commercial transportation (DIFG, 2014c).

A set of scenarios was prepared considering every agency operating independently for both the preparedness and response situations. The performance of each agency showed the absence of an organisation with enough resources to completely cope with any of the disasters at any stage. Then, the most service-oriented result of each agency was aggregated to create a scenario where the response was combined between agencies, in order to evaluate the impact from this approach. As expected, the scenario obtained for every individual case was below the potential results from both optimisation models in every metric, with a consistent expensiveness related to duplication of efforts and inefficient use of resources.

Even compared to the inclusion of agencies focused on particular activities such as food or healthcare, the models have potential benefits because the magnitude of the event can surpass the potential of the agency. For example, 100 people can be enough for distribution at one case, and not for another. As each organisation has limited capacity, the interoperability is crucial for disaster management by mixing resources from every actor involved. The model allows the user to find the most advantageous combination and complement capabilities. The result is a level of flexibility that cannot be attained by current models in the literature focused on these activities.

8.1.4 RQ4: Can a methodology based on GIS and optimisation be built to determine the location of emergency facilities, stock prepositioning, relief distribution and allocation of resources, and improve the activities currently performed by Mexican authorities?

This question is the core of the thesis presented here. This dissertation is pushing the boundaries of research in disaster management by including an original solution for preparedness and response that incorporates multiple organisations. The thesis has demonstrated that a system based on GIS and optimisation can be built to determine the location of emergency facilities, stock prepositioning, relief distribution and allocation of resources. This system is the first of its kind in combining GIS, Optimisation and multi-organisational coordination for this context.

Beyond the theoretical contributions provided by the system, practical value and implications are also relevant. Data from several organisations about three real-world cases was gathered to reconstruct the core decisions taken by Mexican authorities. Data is not perfect and there are pieces that are beyond difficult to gather, but there is confidence on the value of the information obtained and the assumptions incorporated. The *best combination* of the activities undertaken by authorities was obtained by optimising the decisions that could not be recorded. The outcome was used as benchmark to assess the system designed.

Based on the comparisons made on the three cases between the decisions performed by authorities and the results of the model, it is shown that there is room for improvement in several aspects. The integration of GIS into the system allows the user to take advantage of maps and layers already available in Mexico. The goal is to avoid the use of floodable facilities, as has occurred before (Santos-Reyes and Beard, 2011, Santos-Reyes et al., 2010). Having a well-designed plan and a responsive system can prevent the use of unsuitable facilities for sheltering and excessive use of resources. Also, performing scenario analysis can help identify shortcomings in procedures currently applied.

Among the advantages identified, the system proposed can provide support for the analysis of components such as supply capacity and lead time. Exploring the capabilities of the current disaster management system by testing the operational boundaries can avoid an unjustified overconfidence on capacity either from facilities or supply. In that sense, the possibility to balance resources from different actors allows the model to deliver a coordinated response, considering the strength of each one of the organisations. The use of the system proposed can avoid convergence of products and people, allowing the decision maker to deploy only the number of organisations required, and most importantly, the right agencies.

There are challenges to be addressed. Coupling the system designed with traffic assignment for evacuation and routing systems, dealing carefully with the hierarchy of the organisations involved, and handling the preference for inventory management between facilities are some of the most relevant ones. All of these are opportunities to extend this work further.

Based on the results of the evaluation using to the scenario of decisions taken by authorities, and considering the potential improvements that can be delivered by the system, it has been demonstrated that the system designed can improve current operations in the country and it is advancing the field of humanitarian logistics as well.

8.2 Contribution

The purpose of every research is to perform a contribution, i.e. aid in advancing knowledge in the area under study. The system counts with a series of contributions to science along with relevant implications for practitioners. Focusing on the former, in this section each one of the contributions is explained in detail and linked to the content of the dissertation.

The contributions of this research are listed as follows:

- Development of a multi-organisational system for disaster preparedness and response. Chapter 5 introduced the design of a system integrating a GIS and multi-objective optimisation with equity considerations within a multi-organisational perspective. There are no articles on the literature considering multiple organisations and addressing facility location, stock-prepositioning, relief distribution and resource allocation for preparedness and response under the same system. This research accomplished to include that dimension into decision-making by creating two multi-objective optimisation models capable not only of balancing resources from different actors, but also able to select the appropriate number of them and the right organisations to be participating. Optimising actors can allow avoiding convergence, pointing-out strengths and weaknesses of each institution, and designing better plans for disaster management to reduce oversupply and shortages. (RQ4)
- Design of a system for flood preparedness and response based on the Mexican context. The research performed displayed the capability of the Mexican disaster response system and the plethora of resources available for disaster situations. Using the Mexican disaster management structure, results of three case studies in the country presented on Chapter 6 showed the potential to deliver successful operations under different circumstances for a developing country. (RQ1)
- Analysis of coordination and interoperability as crucial elements for disaster management. This research tested the benefits of designing a model considering

collaboration between different partners against independent decision-makers. Chapter 7 showed that a coordinated approach can deliver better results in terms of cost and fill rate. The value of this outcome can be seen more clearly on Sections 7.3.1 and 7.3.2, where the case of Villahermosa shows poor impact of organisations such as Red Cross and NGOs on the overall situation when taken independently, but valuable contributions using a coordinated approach. The results showed how integrating every organisation available into the analysis can yield far better results in terms of care for disaster victims at the same time cost is reduced. (RQ3)

- Analysis of the value of the use of GIS for disaster preparedness. This research showed the potential of using raster GIS for disaster preparedness based on the work of Rodríguez-Espíndola and Gaytán (2015). It included on Chapter 7 an analysis on the expected benefits and drawbacks of the application on three real cases. According to the results, GIS can aid facility location by identifying floodable facilities, potentially avoiding a larger impact on disaster victims. (RQ2)

Similarly, the tool itself contained three components with the following contributions:

- The integration of vector and raster GIS capabilities as input into a system for disaster preparedness and response. As showed on Chapter 3, there is a lack of articles using the capabilities of raster GIS for humanitarian logistics. A cartographic model was used to perform scenario analysis swiftly and serve as input for both models. The cartographic model was supported by vector GIS thereby incorporating successfully the capabilities of both data structures.
- The novel multi-organisation bi-objective multi-commodity multi-modal preparedness model considering equity. The formulation includes the optimisation of the actors with a Min-max approach to provide equity across shelters for facility location, stock prepositioning, relief distribution and resource allocation.
- The novel multi-organisation bi-objective multi-commodity multi-modal response model considering equity. The response formulation includes the multi-organisational perspective into a dynamic model for the entire duration of the flood. To incorporate equity in the design, a constraint based on a minimum amount of aid delivered to all shelters every three periods was included for relief distribution and resource allocation.
- The inclusion of human and material constraints for flood management. Although there are articles considering resource allocation, the majority of articles are discarding human and/or material resources for the problems tackled here. The analysis showed that ranging from cost-effective to service-oriented solutions the allocation of resources can significantly affect the level of service provided to disaster

victims in terms of fill rate. Models disregarding resources can yield sub-optimal solutions.

- Balance between efficiency and effectiveness in both models. Multi-objective optimisation was used to design two models considering two performance measures each. The results showed conflict between both performance measures and flexibility for the decision-maker ranging from efficiency to effectiveness.
- The inclusion of a performance measure for each model considering items and services provided on shelters. Fill rate is measured in terms of relief distribution, healthcare and shelter attention, being an objective function considering the perspective of the service provided within the shelter. This metric is beyond simpler measures and it can be valuable because it is integrating facility location, stock pre-positioning, resource allocation and relief distribution under the same umbrella, with an orientation towards the welfare of disaster victims.

The contributions described above rely on a set of considerations that allow the optimum performance of the system designed. These considerations are presented below:

- The disaster management framework of the country ought to be based on centralised coordination. Coordination is a very complex component of disaster management and as such successful operations are linked to the dynamic of the actors. Having only horizontal coordination would impede the system to work properly, as sharing information can become very challenging and there is no overarching authority directing efforts. There are challenges in centralised coordination such as time of response, bureaucracy and preferential treatment; however the advantages of balancing resources across organisations, clear hierarchies and avoiding jurisdictional issues were prioritised in the design of the model. Having an overarching decision-maker directing operations allows the system to provide the best possible service with efficient use of resources, as the different organisations have to share their available resources, information and comply with the policy selected.
- Data should be accurate and timely available. Data quality is a major factor for the models designed, because optimisation models find the best combination based on the information provided. Any communication issues or obscure information can greatly affect the performance of the system, deriving in inadequate policies and poor operations.
- Accurate forecasting tools. Given the fact that both models are deterministic, the role of the GIS is of paramount importance to introduce the conditions of the disaster and deliver informed decision-making. Reliable and timely forecasts are the input to the GIS procedure, as that information is used to estimate the conditions of the flood.

Delays or mistakes in that information can provoke an exaggeration or underestimation of the situation, causing waste of resources or insufficient response, respectively.

- Availability of resources. It is important to include in the models only the resources at hand and not resources that might be available in the future. The model is assuming that resources can be deployed immediately when needed, and failure to comply with this can create delays in operations.
- Appropriate collaboration. In several cases the models are going to provide solutions that include sharing activities between different actors. It is important that organisations allow sharing material and human resources for the model to provide valuable solutions. Otherwise, operations can be hindered because resources from one actor could not be sufficient for the task.
- The wages for every organisation included should be quatifyable and available. Both models use wages to minimise the number of personnel required for disaster operations. In case wages are not available or considered, the system would prioritise such organisations without really considering the value of including them in the operations.

8.3 Practical implications

A significant component of the research is linked to the application of the research undertaken. Therefore, through the development of this work a series of implications were identified and listed as follows:

- The results obtained in Chapters 6 and 7 suggest important room for improvement in disaster operations in Mexico. The comparison between activities performed by authorities and results from the model display oversupply and shortages, excessive number of actors involved, high cost and improvable fill rates.
- There is a need to define or upgrade current decision making processes in terms of facility location. For instance, in Villahermosa reports of shelters flooded in 2007 (Santos-Reyes et al., 2010, Santos-Reyes and Beard, 2011), the use of police booths as suitable facilities for shelter (SEGOB, 2014a) or reporting over 900 facilities used including a “main square roof to protect people without bathroom nor anything” (PCT, 2014a) is evidence of the need to emphasise mechanisms for facility location.
- The preparedness model can be used to perform scenario analysis aiming to determine the optimal amount of resources required in cases of flood in a region, avoiding decisions based only on the previous event as experienced in Acapulco.

- Both models can be used to test the limits of the system, speeding the request process for help from higher authorities and allowing swift deployment to manage the situation. The models can estimate the impact of different flood conditions to define when aid from higher-level authorities is needed, and also advice when external aid may be needed by showing the operational boundaries of the current system.
- The system developed can be used by authorities to perform planning and response for disaster management under different conditions, and foresee potential complications. It allows the user to identify the right agencies that should be involved and, in the case of the response model, when the agencies are required. This system can also be used a training tool for emergency managers.

8.4 Limitations

During the development of the dissertation some limitations have been identified that are summarised in this section. Even though the purpose was to tackle each one of these limitations when possible, to avoid all of them can be extremely challenging for research.

The first limitation is naturally linked with data. Even though a very important amount of data was collected from around 20 governmental agencies, along with information from Red Cross and other organisations for the case of Villahermosa, there was still data unavailable for the comparison to real conditions. As each agency declared independent ownership of their information, only shelter demand was cross-referenced to ensure accuracy. However, because of the sensibility of the assumptions incorporated and the arguments presented in Section 7.3.2, there is confidence about the results obtained.

For the application of the cases demand information was an important limitation. The maximum number of people sheltered per facility was provided, but not really the amount that got to shelters at the beginning of the disaster. For the purposes of the preparedness model, the maximum demand was used as expected demand, and the actual value was corrected for the response model where the actual value would be known in reality. For demand during the event, reports containing information about demand across time were used to extrapolate the behaviour equally among all shelters. On the other hand, authorities had a record of the number of people that reached shelters but not the origin of them. This was determined using the results from the GIS according to the level of damage of the area. Nonetheless, more thorough records could improve the quality of the analysis performed.

The number of people required for shelter care, healthcare, distribution and DC management was obtained from expert opinion. Values from the organisations were gathered and used according to the case. However, these values could be affected by the productivity and level of energy from personnel.

Noteworthy is the lack of benchmark data to evaluate and compare the mathematical models proposed with other state of the art contributions. Despite the existence of pre-solved conditions used as numerical examples to show the value of models for routing or heuristic solutions, there is no instance prepared to compare contributions addressing facility location, stock prepositioning, relief distribution and resource allocation. It is understandable that each article is including new features that are difficult to foresee, but the lack of a common ground to compare and contrast methods is a considerable limitation of the field. It is a necessity to develop databases that can be used to compare the performance of different models in order to provide solid arguments about the advantages of each contribution, and also to ensure that each new formulation is actually advancing the field of emergency logistics. As it stands at the moment, there is no clear method in humanitarian logistics to verify and validate a model. According to the literature review performed the way authors evaluate their models can be classified into 5 types of methods:

- Comparing the model against a different kind of model or approach. For instance, stochastic vs deterministic, one-stage vs two-stage, macroscopic vs microscopic.
- Comparing the model against another with or without a feature. For example evacuation with and without contraflow, staged and normal evacuation, stochastic solution and perfect information
- Comparison against the result of classic models in the literature
- Sensitivity analysis and scenario analysis
- Comparison to a representation of the current system

For this work it was decided to use the current system as benchmark to show the opportunity to improve current operations; however the lack of information to compare to other methods prevented us from providing more insights about the potential advantages of the models. There is a need to unify the validation methods in the field to provide more reliable solutions and to ease the comparison between different approaches. It can be done by preparing a set of instances with all the information required to test different methods, creating databases available for researchers to actually put their formulations to the test. Doing so is crucial to provide a suitable framework that can be used as benchmark to strengthen the body of research in the field.

Another limitation is linked to evacuation. The system is designed to provide people relocation from demand areas to shelters, but it does not include the traffic assignment. Also, the system is assuming evacuation prior to the flood, requiring excellent planning and appropriate circumstances. Finally, the evacuation distance obtained by the model can be a challenge for decision-makers with high focus on that activity.

The decision-maker should be aware that hierarchies between different organisations cannot be considered by either one of the models directly. The models do not acknowledge the difference between a local and a National agency. Each model only seeks the best possible combination of resources. This shortcoming can be addressed by manually incorporating agencies from the same or adjacent classes on scenario analysis to identify when the barrier is breached, but it adds extra work to the preparation of the model.

Elaborating on equity, for large-scale disasters with significant shortages the use of the constraint related to minimum delivery across all shelters in the response model can be difficult to incorporate, as it can increase solution time considerably.

Finally, to keep linearity of the models, the activation of agencies required the deployment of all of the resources from them. The user should be aware that partial activation of an agency is not possible without modifying the formulation of the models.

8.5 Future research

Given the limitations mentioned and some of the opportunities identified during the development of this work, future research directions are provided to build upon the findings of this research.

The cartographic model was based on Martin (1993) and Rodríguez-Espíndola and Gaytán (2015), whereas the optimisation models were formulated considering the desired outcome, deriving into an abstract system. The next step of this research is to embed the three components into an automated decision-support system that can take inputs and deliver the outputs without need for the user to manage any other parts.

The inclusion of hydrologic factors that can improve the accuracy of the outcome of the GIS would be a valuable addition to this work.

Integrating an algorithm for evacuation and another for routing incorporating a multi-organisational perspective would complement the solutions provided by the model.

The needs of the models designed here call for the development of new forecasting methods that consider not only how many people has to be sheltered, but at which point. A dynamic forecast can be a meaningful addition and a significant aid for response models.

The use of a hierarchical model to consider the classification of each one of the organisations involved in disaster management would be a very important contribution to the multi-organisational approach. Also, the possibility of partially activating agencies could also prove to be advantageous for small to medium scale situations.

From a research perspective, it is important to develop databases of information and instances that can be used as benchmark to test and evaluate new methods in the literature of emergency logistics.

Another venue for future research is related to the integration of NGOs and civil organisations into disaster planning. The purpose would be to analyse the impact of deficient or null coordination to supplement empirically the results obtained here.

Solution time was deemed satisfactory given the planning nature of the models, but the considerable difference found against the combination of two single-objective models calls for the development of a heuristic to improve solution times for large-scale situations.

8.6 Chapter Summary

This chapter included the final arguments of the overall research. At the beginning the research questions were evaluated individually and linked to the content of the dissertation. Afterwards the contributions of this research were listed along with the practical implications identified during the development of the work.

Research is never perfect. Therefore, a set of limitations were mentioned for the reader to have in mind. However, limitations are also opportunities for future developments, and that is highlighted by the last section including some interesting venues for future research identified during the development of this work.

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Appendix A. Verification of the preparedness optimisation model

The verification of the appropriate functioning of the optimisation models was of paramount importance during the design phase of this dissertation. This Appendix includes the list of tests performed to the preparedness model in order to ensure bugs and logical mistakes were eliminated. A numerical example was created in order to make modifications on the data and analyse the results.

Preparedness model

As mentioned on Chapter 5 the code in GAMS was checked to avoid errors there. The coded model is presented on Figure A.1

```
Equations
        ECONSTRAINT         Condition for the e-constraint
        COST                Objective function for the minimization of cost
        MAXD(j)             Maximum disatisfaction per shelter
        UNSPEO(k)           Ammount of people not allocated in shelters
        DEMAND(j)           Product demand
        DEMPROD(j,n)        Demand per product
        UNSDEM(j,n)         Demand unsatisfied by the plan
        MAXUND(j)           Unsatisfied relief demand per shelter
        CAPS(j)             Respect the capacity of shelters
        CAPCD(i)            Respect the capacity of CDs
        SUPCAP(n,o)         Capacity of supply for regional stock
        PREALL(i,n)         Allocation of pre-positioned stock
        DIFHEA(j)           Amount of people not covered for healthcare
        DCOP(i)             DC should not open unless it has enough DC personnel
        SHEOP(j)            Shelter should not open unless it has enough shelter personnel
        CDORG(o)            Personnel of each agency used for DCs
        SORG(o)             Personnel of each agency used for shelters
        HORG(o)             Personnel of each agency used for healthcare
        DORG(o)             Personnel of each agency used for distribution
        TOTPER(o)           Respect the maximum personnel available
        TRWEIGHT(i,j,m)     Link between shipments and trips with weight
        VEHTOT(i,m)         Total trips required
        PERTRA(i,m,o)       Transportation personnel
        ORGVEH(m,o)         Allocation of vehicles of each agency
;
        ECONSTRAINT ..      Z =l= epsilon;
        COST ..             Z =e= sum(i, CA(i)*X(i)) + sum(j, CC(j)*Y(j)) + sum(o, WAGE(o)*W(o)) + sum((i,n,o), CP(n)*PRE(i,n,o)) + sum((i,j,m), CS(i,j,m)*TRAV(i,j,m));
        MAXD(j) ..          MINMAX =g= ((MAD(j) + NVH(j) + NVS(j))/(3*C(j)))*100;
        UNSPEO(k) ..        EP(k) =e= sum(j, DISP (k,j)*SC(k,j));
        DEMAND(j) ..        D(j) =e= sum(k, DISP (k,j));
        DEMPROD(j,n) ..     IPD(j,n)*G(n) =g= D(j);
        UNSDEM(j,n) ..      DSAT(j,n) =e= IPD(j,n) - sum((i,m), SHIP(i,j,m,n));
        MAXUND(j) ..        MAD(j) =g= sum(n, DSAT(j,n)*G(n)*TIER(n))/sum(n, TIER(n));
        CAPS(j) ..          D(j) =l= C(j)*Y(j);
        CAPCD(i) ..         sum((n,o), PRE(i,n,o)*VOL(n)) =l= A(i)*X(i);
        SUPCAP(n,o) ..      sum(i, PRE(i,n,o)) =l= IP(n,o)*W(o);
        PREALL(i,n) ..      sum((j,m), SHIP(i,j,m,n)) =l= sum(o, PRE(i,n,o));
        DIFHEA(j) ..        D(j) =e= sum(o, PH(j,o)*RPH) + NVH(j) - PVH(j);
        DCOP(i) ..          APDC*A(i)*X(i) =l= sum(o, PC(i,o)*RPC);
        SHEOP(j) ..         D(j) =e= sum(o, PS(j,o)*RPS) + NVS(j) - PVS(j);
        CDORG(o) ..         sum(i, PC(i,o)) =l= PAC(o)*W(o);
        SORG(o) ..          sum(j, PS(j,o)) =l= PAS(o)*W(o);
        HORG(o) ..          sum(j, PH(j,o)) =l= PAH(o)*W(o);
        DORG(o) ..          sum((i,m), PD(i,m,o)) =l= PAD(o)*W(o);
        TOTPER(o) ..        sum(i, PC(i,o)) + sum(j, PS(j,o)) + sum((i,m), PD(i,m,o)) =l= TP(o)*W(o);
        TRWEIGHT(i,j,m) ..  sum(n, SHIP(i,j,m,n)*WEI(n)) =l= F(m)*TRAV(i,j,m)*CON(i,j,m)*SA(i,j,m);
        VEHTOT(i,m) ..      sum(j, TRAV(i,j,m)) =l= sum (o, AV(i,m,o)*AVD(m));
        PERTRA(i,m,o) ..    AV(i,m,o) =l= PD(i,m,o)/RDP(m);
        ORGVEH(m,o) ..      sum(i, AV(i,m,o)) =l= TV(m,o)*W(o);
```

Figure A.1. GAMS code of the last version of the preparedness model

A set of randomly generated data was considered with the information portrayed on Table A.1

Table A.1. Sets of the numerical example for the preparedness model

Set	Number	Set	Number
Candidate distribution centres	2	Transportation mode	2
Candidate shelters	4	Products	2
Demand areas	4	Agencies	2

Then the example was solved to check the consistency of the results. For this case, GAMS yielded the results expected by the modeller.

Changing the type of variables (integers into real) was useful to see the improvement in the solution (as expected) and the impact of the relaxation.

The next step was concerned with analysing each one of the constraints individually and components altogether, yielding the results presented below:

- Both objective functions yield the expected results. Cost reduces the use of resources by sacrificing service whereas service sacrifices as many resources as possible to provide adequate service
- Demand at each shelter equals people displaced under different scenarios
- The model is infeasible exceeding the capacity of shelters
- Changes in facility cost lead to changes in the decision for facility location
- The model responds satisfactorily to coverage changes; poor coverage can produce infeasibility
- The use of MINIMAX as a measure of equity is obtaining successful results. The comparison with and without the min – max approach shows that with the measure the aid is distributed across all of the shelters whereas the absence of it leads to more satisfaction for the big shelter
- The model is successfully minimising the number of agencies involved when the cost objective function is involved in the analysis (not applicable to only minimising unfulfillment)
- The model selects whether there is enough inventory or not to satisfy demand and applies the corresponding rule for pre-positioning
- When there are enough items and resources (personnel and vehicles), the demand is completely satisfied
- When supply cannot cover demand, the supplies are sent depending on resource availability and the objective functions
- The system decides properly when there is enough supply for one item and not enough for another
- The system decides properly when there is not enough supply to satisfy the demand of all items
- Connectivity affects the selection of shelters and distribution centres successfully and it can lead to infeasibility, similarly to coverage
- The calculations of DSAT and MAD are accurate.
- Changes in DC capacity affect the decision of which facility to open, the DCs can share stock as long as there is enough personnel. The lack of space leads to unfeasibility
- Pre-positioned inventory is dependent on the supply availability and it may lead to shortages
- Shipments remain dependent on stock availability and can lead also to shortages
- MINIMAX chooses the greatest value for every dimension (shelter, relief and healthcare) and obtains the maximum number of people dissatisfied.
- The constraint of overall personnel governs individual constraints
- The number of people available affects distribution location when there is not enough people to open the biggest DC
- The number of trips depends con coverage, connectivity and it controls shipments

Appendix B. Verification of the response optimisation model

The verification of the appropriate functioning of the optimisation models was of paramount importance during the design phase of this dissertation. This Appendix includes the list of tests performed to the response model in order to ensure bugs and logical mistakes were eliminated. A numerical example was created in order to make modifications on the data and analyse the results.

Response model

Initially the model was coded into GAMS and checked for any logical errors. Figure B.1 shows the coded model.

```
MINIMAX                 Maximum demand unsatisfied per period
VDSAT                   Calculation of DSAT
THRESHOLD               Minimum percentage of demand to satisfy every two periods
INVDA                   Inventory level at demand area at the beggining of the period
INVDC                   Inventory level at DC at the beggining of the period
SUPCAP                  Total supply capacity
DCCAP                   DC capacity
DACAP                   Shelter capacity
DCOP                    Number of personnel required for DC operation
DIFHEA                  Amount of healthcare personnel
SHEOP                   Amount of shelter personnel
DCPER                   Rotation of DC personnel
SPER                    Rotation of shelter personnel
HPER                    Rotation of healthcare personnel
DPER                    Rotation of distribution personnel
SORG                    Maximum number of personnel of each agency available for shelters
HORG                    Maximum number of personnel of each agency available for healthcare
MAXDCPER                Maximum number of DC personnel available
MADDPER                 Maximum number of distribution personnel available
MAXPER                  Maximum number of overall personnel available
TRWEIGHT                Link between shipments and trips with weight
VEHTOT                  Total trips required
PERTRA                  Transportation personnel
ORGVEH                  Allocation of vehicles of each agency;

ECONSTRAINT ..          z =l= epsilon;
RESOURCES ..            z =e= sum((o,t), WAGE(o,t)*W(o,t)) + sum((i,n,o,t), CP(n)*SUP(i,n,o,t)) + sum((i,j,m,t), CS(i,j,m)*TRAV(i,j,m,t));
DISSATISFACTION ..      zz =e= sum((j,t), MAD(j,t) + NVH(j,t) + NVS(j,t));
MINIMAX(j,t) ..         MAD(j,t) =e= sum(n, DSAT(j,n,t)*G(n)*PRI(n))/sum(n, PRI(n));
VDSAT(j,n,t) ..         DSAT(j,n,t) =e= IPD(j,n,t) - TSC(j,n,t);
THRESHOLD(j,n,t) ..     TSC(j,n,t) + TSC(j,n,t+1) + TSC(j,n,t+2) =g= (IPD(j,n,t) + IPD(j,n,t+1) + IPD(j,n,t+2))*SL(n);
INVDA(j,n,t) ..         INV(j,n,t) =e= INV(j,n,t-1) + sum((i,m), SHIP (i,j,m,n,t)) - TSC(j,n,t) + SI0(j,n,t) ;
INVDC(i,n,t) ..         IL(i,n,t) =e= IL(i,n,t-1) + sum(o, SUP(i,n,o,t)) - sum((j,m), SHIP(i,j,m,n,t)) + DI0(i,n,t);
SUPCAP(n,o,t) ..        sum(i, SUP(i,n,o,t)) =l= SC(n,o,t)*W(o,t);
DCCAP(i,t) ..           sum(n, IL(i,n,t)*VOL(n)) =l= A(i);
DACAP(j,t) ..           sum(n, INV(j,n,t)*VOL(n)) =l= CI(j)*TYPE(j);
DCOP(i,t) ..            APDC*A(i) =l= sum(o, PC(i,o,t)*RPC);
DIFHEA(j,t) ..          D(j,t)*TYPE(j) =e= sum(o, PH(j,o,t)*RPH) + NVH(j,t) - PVH(j,t);
SHEOP(j,t) ..           D(j,t)*TYPE(j) =e= sum(o, PS(j,o,t)*RPS) + NVS(j,t) - PVS(j,t);
DCPER(i,o,t) ..         PC(i,o,t) =e= PC(i,o,t-1) + APC(i,o,t) - DPC(i,o,t) + PC0(i,o,t);
SPER(j,o,t) ..          PS(j,o,t) =e= PS(j,o,t-1) + APS(j,o,t) - DPS(j,o,t) + PS0(j,o,t);
HPER(j,o,t) ..          PH(j,o,t) =e= PH(j,o,t-1) + APH(j,o,t) - DPH(j,o,t) + PH0(j,o,t);
DPER(i,m,o,t) ..        PD(i,m,o,t) =e= PD(i,m,o,t-1) + APD(i,m,o,t) - DPD(i,m,o,t) + PD0(i,m,o,t);
SORG(o,t) ..            sum(j, PS(j,o,t)) =l= PAS(o,t)*W(o,t);
HORG(o,t) ..            sum(j, PH(j,o,t)) =l= PAH(o,t)*W(o,t);
MAXDCPER(o,t) ..        sum(i, PC(i,o,t)) =l= PAC(o,t)*W(o,t);
MADDPER(o,t) ..         sum((i,m), PD(i,m,o,t)) =l= PAD(o,t)*W(o,t);
MAXPER(o,t) ..          sum(i, PC(i,o,t)) + sum(j, PS(j,o,t)) + sum((i,m), PD(i,m,o,t)) =l= TRP(o,t)*W(o,t);
TRWEIGHT(i,j,m,t) ..    sum(n, SHIP(i,j,m,n,t)*WEI(n)) =l= F(m)*TRAV(i,j,m,t)*CON(i,j,m,t)*SA(i,j,m);
VEHTOT(i,m,t) ..        sum(j, TRAV(i,j,m,t)) =l= sum (o, AV(i,m,o,t)*AVD(m));
PERTRA(i,m,o,t) ..      AV(i,m,o,t) =l= PD(i,m,o,t)/RDP(m);
ORGVEH(m,o,t) ..        sum(i, AV(i,m,o,t)) =l= TV(m,o,t)*W(o,t);
```

Figure B.1. GAMS code of the last version of the response model

Based on the previous case a hypothetical example was checked to ensure the appropriate performance of the model, and the parameters are presented on Table B.1.

Table B.1 Sets of the numerical example for the response model

Set	Number	Set	Number
Supply facilities	2	Products	3
Demand areas	4	Agencies	3
Transportation mode	2	Time periods	5

Running the example the results were consistent with the expectations, and changing integer variables into real variables yielded the improvement in the objective function known beforehand.

After the initial checks were performed a series of changes on the data was performed to analyse the performance of constraints and components (sets of constrains such as personnel, transportation, among others). The result of that set of tests was:

- There was a trade-off between objectives as these showed to be in conflict
- The model was able to minimise the number of agencies required according to demand as long as the cost objective function was activated
- The model can reduce the number of agencies required in total and for each one of the time periods, closing big agencies when these are not required
- Without the equity measure the model provides more support on biggest shelters and it can reach a lower number of people dissatisfied
- The threshold constraint provides equity but solution time is slightly increased and it holds the possibility for infeasibility. Also this constraint was tried with two periods instead of three but it can yield infeasibility very easily
- The calculations of DSAT and MAD are accurate
- The calculations for INV and IL across time periods are all right
- The system tends to push inventory towards shelters to minimise the number of trips and also the number of people required at DCs
- Initial conditions are working properly
- Product capacity of the agencies activated is respected by the model
- Shelter and DC capacity in terms of storage are bounding appropriately the solution. These equations can cause infeasibility if there is a lack of storage space overall
- The parameter of type of demand area (shelter or other area) works fine and differentiates both of the options with the binary variable
- The variables of rotation of personnel are working adequately
- The model is respecting the number of employees available according to the agencies activated
- The model responds satisfactorily to coverage and connectivity changes; poor coverage or connectivity can produce infeasibility
- When there are enough items and resources (personnel and vehicles), the demand is completely satisfied
- The system decides adequately when there is enough supply to satisfy the whole demand
- Pre-positioned inventory from a previous stage is adequately used and the number of items in inventory tends to zero at the end of the time periods
- Shipments remain dependent on stock availability and can lead to shortages
- The constraint of overall personnel governs individual constraints

After the analysis the conclusion is that both models operate within the bounds of the expected results, there does not seem to be a problem in the logic of either of the models and both are approved to be analysed further with the case studies.

APPENDIX C. INFORMATION REQUESTS MADE FOR THE CASE STUDIES

Veracruz

A list of the requests filed to different agencies was kept and used to create a matrix of the results. Some of the agencies claimed not to have jurisdiction or information available, which was reflected on the list as an outcome of "No", whereas "Yes" was used when the information was satisfactory and "Partially" when the information was indirectly reflecting what was required. The folio is the number adhered to the request, the source the organisation enquired, the date for recording purposes, the class includes the folder in the storage drive, the content highlights the purpose of the request, the area describes the region of interest and the year focuses on the date of the event. Table C.1 presents the requests filed to regional authorities in the city of Veracruz.

Table C.1 Regional enquiries for Veracruz

Folio	Source	Enquiry date	Class	Content	Area	Year	Outcome
00430114	PC	28/05/2014	PC	Shelters used	Veracruz	2010	Yes
00430214	SSP	28/05/2014	SSP	Shelters used	Veracruz	2010	No
00430314	SS	28/05/2014	SS	Shelters used	Veracruz	2010	Yes
00430414	SEDESOL	28/05/2014	SEDESOL	Personnel used and activities	Veracruz	2010	No
00430514	PC	28/05/2014	PC	Personnel used and activities	Veracruz	2010	Yes
00430614	SS	28/05/2014	SS	Personnel used and activities	Veracruz	2010	Yes
00430714	SSP	28/05/2014	SSP	Personnel used and activities	Veracruz	2010	No
00430814	SEDESOL	28/05/2014	SEDESOL	Vehicles used	Veracruz	2010	No
00430914	PC	28/05/2014	PC	Vehicles used	Veracruz	2010	Yes
00431014	SS	28/05/2014	SS	Vehicles used	Veracruz	2010	Yes
00431114	SSP	28/05/2014	SSP	Vehicles used	Veracruz	2010	No
00431214	SEDESOL	28/05/2014	SEDESOL	DCs used	Veracruz	2010	No
00431314	PC	28/05/2014	PC	DCs used	Veracruz	2010	Yes
00431414	SSP	28/05/2014	SSP	DCs used	Veracruz	2010	No
00431514	PC	28/05/2014	PC	Shelters available	Veracruz	2010	Yes
00431614	SS	28/05/2014	SS	Shelters available	Veracruz	2010	No

00431714	SSP	28/05/2014	SSP	Shelters available	Veracruz	2010	No
00431814	PC	28/05/2014	PC	Headquarters used	Veracruz	2010	No
00431914	SEDESOL	28/05/2014	SEDESOL	Headquarters used	Veracruz	2010	No
00432014	SEDESOL	28/05/2014	SEDESOL	Personnel required for shelter care	Veracruz	2010	No
00432114	PC	28/05/2014	PC	Personnel required for shelter care	Veracruz	2010	Yes
00432214	SS	28/05/2014	SS	Personnel required for shelter care	Veracruz	2010	No
00432314	SSP	28/05/2014	SSP	Personnel required for shelter care	Veracruz	2010	No
00432414	PC	28/05/2014	PC	Required healthcare personnel	Veracruz	2010	Yes
00432514	SS	28/05/2014	SS	Required healthcare personnel	Veracruz	2010	No
00432614	SEDESOL	28/05/2014	SEDESOL	Required distribution personnel	Veracruz	2010	No
00432714	PC	28/05/2014	PC	Required distribution personnel	Veracruz	2010	Yes
00432814	SSP	28/05/2014	SSP	Required distribution personnel	Veracruz	2010	No
00613014	DIF	25/07/2014	DIF	DCs available	Veracruz	2010	No
00613014	DIF	25/07/2014	DIF	DCs used	Veracruz	2010	No
00613014	DIF	25/07/2014	DIF	DC capacity	Veracruz	2010	No
00613114	DIF	25/07/2014	DIF	Used agency personnel for DC	Veracruz	2010	No
00613114	DIF	25/07/2014	DIF	Used agency personnel for shelter	Veracruz	2010	No
00613114	DIF	25/07/2014	DIF	Used agency personnel for distribution	Veracruz	2010	No
00613114	DIF	25/07/2014	DIF	Total personnel per agency	Veracruz	2010	No
00613214	DIF	25/07/2014	DIF	Weight vehicle capacity	Veracruz	2010	No
00613214	DIF	25/07/2014	DIF	Vehicles used	Veracruz	2010	No
00613314	SVERACRUZ	25/07/2014	SVERACRUZ	Procurement per product	Veracruz	2010	No
00613514	SVERACRUZ	25/07/2014	SVERACRUZ	Product inventory available per organisation	Veracruz	2010	No
00613414	SVERACRUZ	25/07/2014	SVERACRUZ	Supply capacity	Veracruz	2010	Partially
00613414	SVERACRUZ	25/07/2014	SVERACRUZ	Supply lead time	Veracruz	2010	Partially
00613614	SVERACRUZ	25/07/2014	SVERACRUZ	Shipment diary	Veracruz	2010	Partially
00613714	PC	25/07/2014	PC	Shelter capacity	Veracruz	2010	Yes

00613714	PC	25/07/2014	PC	Fixed cost shelters	Veracruz	2010	No
00613814	PC	25/07/2014	PC	Available agency personnel for DC	Veracruz	2010	Yes
00613814	PC	25/07/2014	PC	Available agency personnel for shelter	Veracruz	2010	Yes
00613814	PC	25/07/2014	PC	Available agency personnel for healthcare	Veracruz	2010	No
00613814	PC	25/07/2014	PC	Available agency personnel for distribution	Veracruz	2010	Yes
00614014	PC	25/07/2014	PC	Product inventory available per organisation	Veracruz	2010	No
00613914	PC	25/07/2014	PC	Supply capacity	Veracruz	2010	No
00613914	PC	25/07/2014	PC	Supply lead time	Veracruz	2010	Partially
00614114	PC	25/07/2014	PC	Food pantries delivered	Veracruz	2010	No
00614114	PC	25/07/2014	PC	Other items delivered	Veracruz	2010	No
00614114	PC	25/07/2014	PC	Shipment diary	Veracruz	2010	No
00614214	SEGOB	25/07/2014	SEGOB	Shelters used	Veracruz	2010	No
00614214	SEGOB	25/07/2014	SEGOB	Shelter capacity	Veracruz	2010	No
00614314	SEGOB	25/07/2014	SEGOB	Shelter history per state	Veracruz	2010	No
00614414	SEGOB	25/07/2014	SEGOB	Evolution of shelters over time	Veracruz	2010	No
00614614	SEGOB	25/07/2014	SEGOB	Supply capacity	Veracruz	2010	No
00614714	SEGOB	25/07/2014	SEGOB	Other items delivered	Veracruz	2010	No
00614514	SEGOB	25/07/2014	SEGOB	DCs used	Veracruz	2010	No
00715014	SEGOB	08/09/2014	SEGOB	Personnel and vehicles used per agency	Veracruz	2010	No

In terms of the National enquiries, Table C.2 displays details about the requests submitted to National governmental bodies.

Table C.2. National enquiries for Veracruz

Folio	**Source**	**Enquiry date**	**Class**	**Content**	**Area**	**Outcome**
0000400101914	SEGOB	02/04/2014	SEGOB	Lead time distribution in disasters	Mexico	Partially
0000400160314	SEGOB	25/06/2014	SEGOB	Medicines distributed	Acapulco, Villahermosa and Veracruz	Yes
0000700002514	SEDENA	06/01/2014	SEDENA	Transportation cost per vehicle per km	Mexico	Yes

0000700002614	SEDENA	06/01/2014	SEDENA	Type and number of available vehicles for distribution	Mexico	Yes
0000700003214	SEDENA	06/01/2014	SEDENA	Personnel distribution for shelters	Mexico	Yes
0000700003314	SEDENA	06/01/2014	SEDENA	Personnel distribution for DCs	Mexico	No
0000700004914	SEDENA	06/01/2014	SEDENA	Distribution personnel	Mexico	Yes
0000700013014	SEDENA	15/01/2014	SEDENA	Cost healthcare centres	Mexico	No
0000700014714	SEDENA	17/01/2014	SEDENA	DN-III Plan	Mexico	Partially
0000700031214	SEDENA	14/02/2014	SEDENA	Available personnel and activities	Mexico	No
0001200008314	SMEXICO	06/01/2014	SMEXICO	Required medicines per 100 people	Mexico	Yes
0001200021314	SMEXICO	15/01/2014	SMEXICO	Procedure manuals for healthcare centres	Mexico	No
1236000003414	DIF	17/01/2014	DIF	Activity reports	Veracruz, Guerrero and Tabasco	Yes
1236000003514	DIF	17/01/2014	DIF	Operation manuals	Mexico	Partially
2015000001614	DICONSA	06/01/2014	DICONSA	Holding cost	Mexico	No
2015000001714	DICONSA	06/01/2014	DICONSA	Cost per vehicle per km	Mexico	No
2015000007014	DICONSA	02/04/2014	DICONSA	Supply capacity	Mexico	Yes
2015000008113	DICONSA	10/07/2013	DICONSA	Price list for floods	Veracruz, Guerrero and Tabasco	Partially
2015000008213	DICONSA	10/07/2013	DICONSA	Pre-positioned stock	Veracruz, Guerrero and Tabasco	Yes
0064101318214	IMSS	28/05/2014	IMSS	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	Yes
1236000015714	DIF	28/05/2014	DIF	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0001200185714	SMEXICO	28/05/2014	SMEXICO	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0000400160214	SEGOB	28/05/2014	SEGOB	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0002000092414	SEDESOL	28/05/2014	SEDESOL	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0064101318414	IMSS	28/05/2014	IMSS	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
1236000015814	DIF	28/05/2014	DIF	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0001200185814	SMEXICO	28/05/2014	SMEXICO	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160314	SEGOB	28/05/2014	SEGOB	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Partially
0002000092514	SEDESOL	28/05/2014	SEDESOL	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092614	SEDESOL	28/05/2014	SEDESOL	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No

0000700097214	SEDENA	28/05/2014	SEDENA	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160414	SEGOB	28/05/2014	SEGOB	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
1236000015914	DIF	28/05/2014	DIF	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0001300043014	SEMAR	28/05/2014	SEMAR	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092714	SEDESOL	28/05/2014	SEDESOL	Shipment diary and leat dime	Veracruz, Guerrero and Tabasco	No
0000700097314	SEDENA	28/05/2014	SEDENA	Shipment diary and lead time	Veracruz, Guerrero and Tabasco	No
0000400160514	SEGOB	28/05/2014	SEGOB	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
1236000016014	DIF	28/05/2014	DIF	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043114	SEMAR	28/05/2014	SEMAR	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043214	SEMAR	28/05/2014	SEMAR	Satellite images	Veracruz, Guerrero and Tabasco	Yes
0000400160614	SEGOB	28/05/2014	SEGOB	International aid	Veracruz, Guerrero and Tabasco	No
0000500088214	SRE	28/05/2014	SRE	International aid	Veracruz, Guerrero and Tabasco	YES
0000700097414	SEDENA	28/05/2014	SEDENA	Shelters used and capacity	Veracruz	Yes
1236000016114	DIF	28/05/2014	DIF	Shelters used and capacity	Veracruz	No
0064101319114	IMSS	28/05/2014	IMSS	Personnel used and activities	Veracruz	Yes
0000700097514	SEDENA	28/05/2014	SEDENA	Personnel used and activities	Veracruz	Yes
0001300043314	SEMAR	28/05/2014	SEMAR	Personnel used and activities	Veracruz	No
0002000092814	SEDESOL	28/05/2014	SEDESOL	Personnel used and activities	Veracruz	No
0001200186014	SMEXICO	28/05/2014	SMEXICO	Personnel used and activities	Veracruz	No
2015000009914	DICONSA	28/05/2014	DICONSA	Personnel used and activities	Veracruz	Yes
0064101319514	IMSS	28/05/2014	IMSS	Vehicles used	Veracruz	Yes
0000700097614	SEDENA	28/05/2014	SEDENA	Vehicles used	Veracruz	No
0001300043514	SEMAR	28/05/2014	SEMAR	Vehicles used	Veracruz	Yes
0002000092914	SEDESOL	28/05/2014	SEDESOL	Vehicles used	Veracruz	No
0001200186114	SMEXICO	28/05/2014	SMEXICO	Vehicles used	Veracruz	Yes
2015000010014	DICONSA	28/05/2014	DICONSA	Vehicles used	Veracruz	Yes
0002000093014	SEDESOL	28/05/2014	SEDESOL	CDs used and capacity	Veracruz	No

0000700097714	SEDENA	28/05/2014	SEDENA	CDs used and capacity	Veracruz	Yes
2015000010114	DICONSA	28/05/2014	DICONSA	CDs used and capacity	Veracruz	Yes
0000700097814	SEDENA	28/05/2014	SEDENA	Shelters available and capacity	Veracruz	No
1236000016214	DIF	28/05/2014	DIF	Shelters available and capacity	Veracruz	No
0000700097914	SEDENA	28/05/2014	SEDENA	Headquarters used	Veracruz	No
0002000093114	SEDESOL	28/05/2014	SEDESOL	Headquarters used	Veracruz	No
2015000010214	DICONSA	28/05/2014	DICONSA	Headquarters used	Veracruz	Yes
0413000006914	CENAPRED	28/05/2014	CENAPRED	Satellite images	Veracruz	Yes
0002000093214	SEDESOL	28/05/2014	SEDESOL	Required shelter and DC personnel	Mexico	No
2015000010314	DICONSA	28/05/2014	DICONSA	Required shelter and DC personnel	Mexico	No
0001200186214	SMEXICO	28/05/2014	SMEXICO	Required shelter and DC personnel	Mexico	No
0001300043614	SEMAR	28/05/2014	SEMAR	Required shelter and DC personnel	Mexico	No
1236000016314	DIF	28/05/2014	DIF	Required shelter and DC personnel	Mexico	No
0001200186414	SMEXICO	28/05/2014	SMEXICO	Required healthcare personnel	Mexico	No
0064101320214	IMSS	28/05/2014	IMSS	Required healthcare personnel	Mexico	Yes
0002000093314	SEDESOL	28/05/2014	SEDESOL	Required personnel for distribution	Mexico	No
2015000010414	DICONSA	28/05/2014	DICONSA	Required personnel for distribution	Mexico	Yes
1236000016414	DIF	28/05/2014	DIF	Required personnel for distribution	Mexico	No
0002000114814	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock currently	Acapulco, Villahermosa and Veracruz	No
0002000114914	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock used	Acapulco, Villahermosa and Veracruz	No
0001200234314	SMEXICO	11/07/2014	SMEXICO	Content of the disaster kit of medicines	Mexico	Yes
0001200234414	SMEXICO	11/07/2014	SMEXICO	Healthcare personnel used	Veracruz	No
1236000021814	DIF	25/07/2014	DIF	Procurement per product	Veracruz	No
1236000021914	DIF	25/07/2014	DIF	Used agency personnel for DC	Veracruz	Yes
1236000021914	DIF	25/07/2014	DIF	Used agency personnel for shelter	Veracruz	Yes
1236000021914	DIF	25/07/2014	DIF	Used agency personnel for distribution	Veracruz	Yes
1236000021914	DIF	25/07/2014	DIF	Total personnel per agency	Veracruz	Yes

1236000022014	DIF	25/07/2014	DIF	Weight vehicle capacity	Veracruz	Yes
1236000022014	DIF	25/07/2014	DIF	Vehicles used	Veracruz	No
1236000022314	DIF	25/07/2014	DIF	Product inventory available per organisation	Veracruz	No
1236000022114	DIF	25/07/2014	DIF	Supply capacity	Veracruz	No
1236000022114	DIF	25/07/2014	DIF	Supply lead time	Veracruz	No
1236000022214	DIF	25/07/2014	DIF	Food pantries delivered	Veracruz	No
1236000022214	DIF	25/07/2014	DIF	Other items delivered	Veracruz	No
1236000022414	DIF	25/07/2014	DIF	Shipment diary	Veracruz	No
0001200249214	SMEXICO	24/07/2014	SMEXICO	Procurement per product	Veracruz	Yes
0001200249314	SMEXICO	24/07/2014	SMEXICO	Product inventory available per organisation	Veracruz	No
0001200249414	SMEXICO	24/07/2014	SMEXICO	Supply capacity	Veracruz	No
0001200249614	SMEXICO	24/07/2014	SMEXICO	Shipment diary	Veracruz	Yes
0000700144014	SEDENA	25/07/2014	SEDENA	Shipment diary	Veracruz	Partially
2015000012814	DICONSA	24/07/2014	DICONSA	Fixed cost DCs	Veracruz	No
2015000013114	DICONSA	25/07/2014	DICONSA	Available agency personnel for DC	Veracruz	Yes
2015000013114	DICONSA	25/07/2014	DICONSA	Available agency personnel for distribution	Veracruz	Yes
2015000012914	DICONSA	25/07/2014	DICONSA	Food pantries delivered	Veracruz	Yes
2015000012914	DICONSA	25/07/2014	DICONSA	Other items delivered	Veracruz	Yes
2015000013014	DICONSA	25/07/2014	DICONSA	Shipment diary	Veracruz	No
0000400233814	SEGOB	25/07/2014	SEGOB	Shelters used	Acapulco, Villahermosa and Veracruz	Partially
0000400233914	SEGOB	25/07/2014	SEGOB	Shelter history per state	Acapulco, Villahermosa and Veracruz	Yes
0000400234014	SEGOB	25/07/2014	SEGOB	Evolution of shelters over time	Acapulco, Villahermosa and Veracruz	No
0000400234114	SEGOB	25/07/2014	SEGOB	DCs used	Acapulco, Villahermosa and Veracruz	No
0000400234214	SEGOB	25/07/2014	SEGOB	Supply capacity	Acapulco, Villahermosa and Veracruz	No
0000400256014	SEGOB	25/07/2014	SEGOB	Other items delivered	Acapulco, Villahermosa and Veracruz	No
0064101758914	IMSS	25/07/2014	IMSS	Shelters available	Veracruz	No
0064101758914	IMSS	25/07/2014	IMSS	Shelters used	Veracruz	No

0064101758914	IMSS	25/07/2014	IMSS	Shelter capacity	Veracruz	No
0064101759014	IMSS	25/07/2014	IMSS	Procurement per product	Veracruz	No
0064101759114	IMSS	25/07/2014	IMSS	Product inventory available per organisation	Veracruz	No
0064101759214	IMSS	25/07/2014	IMSS	Shipment diary	Veracruz	Partially
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for DC	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for shelter	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for healthcare	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for distribution	Acapulco, Villahermosa and Veracruz	No
0000400265114	SEGOB	28/08/2014	SEGOB	Total personnel and vehicles used	Veracruz	No
2015000016014	DICONSA	07/10/2014	DICONSA	Procurement per product	Veracruz	No

Acapulco

For Acapulco, the number of State agencies enquired was shorter given the options of the transparency system (aggregating different agencies into an overarching body) as shown by Table C.3, with the number of requests being slightly larger than the ones performed in Veracruz. The reason is because of more positive responses for this case and the larger number of organisations involved. The reason can be attributed to the still recent nature of the flood in Acapulco, although the greater publicity to this disaster could be also a major driver.

As result from the requests some of the agencies claimed not to have jurisdiction or information available, which was reflected on the list as an outcome of “No”, whereas “Yes” was used when the information was satisfactory and “Partially” when the information was indirectly reflecting what was required. The folio is the number adhered to the request, the source the organisation enquired, the date for recording purposes, the class includes the folder in the storage drive, the content highlights the purpose of the request, the area describes the region of interest and the year focuses on the date of the event.

Table C.3 Regional enquiries

Folio	Source	Enquiry date	Class	Content	Area	Year	Outcome
00000114	SSPPC	04/02/2014	SSPPC	Shelters used	Acapulco	2013	Yes
00000214	SSPPC	04/02/2014	SSPPC	Available shelters	Acapulco	Currently	Yes
00000314	SSPPC	04/02/2014	SSPPC	Available DCs	Acapulco	Currently	Yes

00000414	SSPPC	04/02/2014	SSPPC	CDs used	Acapulco	2013	Yes
00000514	SSPPC	04/02/2014	SSPPC	Cost shelters	Acapulco	2013	No
00000614	SSPPC	04/02/2014	SSPPC	Personnel used and activities	Acapulco	2013	Yes
00000714	SSPPC	04/02/2014	SSPPC	Shelter personnel needed	Acapulco	2013	Yes
00000814	SSPPC	04/02/2014	SSPPC	DC personnel required	Acapulco	2013	Yes
00000914	SSPPC	04/02/2014	SSPPC	Vehicles used	Acapulco	2013	Yes
00001014	SSPPC	04/02/2014	SSPPC	Healthcare facilities	Acapulco	2013	No
00001114	SGUERRERO	03/02/2014	SGUERRERO	Shelters used	Acapulco	2013	No
00001214	SSPPC	09/05/2014	SSPPC	Technical report	Acapulco	2013	Partially
00005814	DIF	03/02/2014	DIF	Shelters used	Acapulco	2013	No
00005914	DIF	04/02/2014	DIF	DCs used	Acapulco	2013	Yes
00006014	DIF	04/02/2014	DIF	Headquarters used	Acapulco	2013	Yes
00006114	DIF	04/02/2014	DIF	Personnel used and activities	Acapulco	2013	Yes
00006214	DIF	04/02/2014	DIF	Vehicles used	Acapulco	2013	Yes
00006314	DIF	04/02/2014	DIF	Cost shelters	Acapulco	2013	No
00006414	DIF	04/02/2014	DIF	Food pantries distributed	Acapulco	2013	Yes
00026214	SGUERRERO	09/05/2014	SGUERRERO	Personnel used and activities	Acapulco	2013	Yes
00026314	SGUERRERO	09/05/2014	SGUERRERO	Vehicles used	Acapulco	2013	Yes
00026414	SGUERRERO	09/05/2014	SGUERRERO	Available personnel and activities	Acapulco	Currently	Yes
00026514	SGUERRERO	09/05/2014	SGUERRERO	Available vehicles	Acapulco	Currently	Yes
00026614	SEDESOL	09/05/2014	SEDESOL	Personnel used and activities	Acapulco	2013	Yes
00026714	SEDESOL	09/05/2014	SEDESOL	Vehicles used	Acapulco	2013	Yes
00026814	SEDESOL	09/05/2014	SEDESOL	Available personnel and activities	Acapulco	Currently	No
00026914	SEDESOL	09/05/2014	SEDESOL	Available vehicles	Acapulco	Currently	No
00027014	DIF	09/05/2014	DIF	Personnel used and activities	Acapulco	2013	Yes
00027114	DIF	09/05/2014	DIF	Vehicles used	Acapulco	2013	Yes
00027214	DIF	09/05/2014	DIF	Available personnel and activities	Acapulco	Currently	No

00027314	DIF	09/05/2014	DIF	Available vehicles	Acapulco	Currently	No
00087814	SGUERRERO	06/06/2014	SGUERRERO	Shelter history	Guerrero	2013	No
00087914	SEDESOL	06/06/2014	SEDESOL	Shelter history	Guerrero	2013	No
00088014	PC	06/06/2014	PC	Shelter history	Guerrero	2013	No
00088114	SGUERRERO	06/06/2014	SGUERRERO	Monthly shelter demand	Guerrero	2013	No
00088214	SEDESOL	06/06/2014	SEDESOL	Monthly shelter demand	Guerrero	2013	No
00088314	PC	06/06/2014	PC	Monthly shelter demand	Guerrero	2013	Yes
00088414	SGUERRERO	06/06/2014	SGUERRERO	Required healthcare personnel	Mexico	Currently	Yes
00088514	PC	06/06/2014	PC	Required healthcare personnel	Mexico	Currently	No
00088614	SEDESOL	06/06/2014	SEDESOL	Required distribution personnel	Mexico	Currently	Yes
00088714	PC	06/06/2014	PC	Required distribution personnel	Mexico	Currently	Yes
00093614	PC	23/06/2014	PC	DC capacity	Acapulco	2013	Partially
00093714	DIF	23/06/2014	DIF	DC capacity	Acapulco	2013	No
00096214	PC	30/06/2014	PC	Shelter personnel used	Acapulco	2013	Yes
00100914	PC	06/06/2014	PC	Shelter history	Guerrero	2013	Yes
106814	DIF	24/07/2014	DIF	Fixed cost DCs	Acapulco	2013	No
107114	DIF	24/07/2014	DIF	Procurement per product	Acapulco	2013	No
107214	DIF	24/07/2014	DIF	Available agency personnel for distribution	Acapulco	2013	No
107314	DIF	24/07/2014	DIF	Product inventory available per organisation	Acapulco	2013	No
107414	DIF	24/07/2014	DIF	Holding cost	Acapulco	2013	No
107614	SGUERRERO	24/07/2014	SGUERRERO	Procurement per product	Acapulco	2013	Yes
107514	SGUERRERO	24/07/2014	SGUERRERO	Available agency personnel for healthcare	Acapulco	2013	Yes
107814	SGUERRERO	24/07/2014	SGUERRERO	Product inventory available per organisation	Acapulco	2013	
107714	SGUERRERO	24/07/2014	SGUERRERO	Supply capacity	Acapulco	2013	No
107714	SGUERRERO	24/07/2014	SGUERRERO	Supply lead time	Acapulco	2013	No
107914	SGUERRERO	24/07/2014	SGUERRERO	Holding cost	Acapulco	2013	No
108014	SGUERRERO	24/07/2014	SGUERRERO	Shipment diary	Acapulco	2013	

108114	SEDESOL	24/07/2014	SEDESOL	DCs available	Acapulco	2013	No
108114	SEDESOL	24/07/2014	SEDESOL	Capacities DCs available	Acapulco	2013	No
108114	SEDESOL	24/07/2014	SEDESOL	DCs used	Acapulco	2013	No
108214	SEDESOL	24/07/2014	SEDESOL	Fixed cost DCs	Acapulco	2013	
108314	SEDESOL	24/07/2014	SEDESOL	Available agency personnel for distribution	Acapulco	2013	Yes
108414	SEDESOL	24/07/2014	SEDESOL	Vehicles available	Acapulco	2013	Yes
108514	PC	24/07/2014	PC	Fixed cost DCs	Acapulco	2013	No
108614	PC	24/07/2014	PC	Available agency personnel for DC	Acapulco	2013	No
108614	PC	24/07/2014	PC	Available agency personnel for shelter	Acapulco	2013	No
108614	PC	24/07/2014	PC	Available agency personnel for healthcare	Acapulco	2013	No
108614	PC	24/07/2014	PC	Available agency personnel for distribution	Acapulco	2013	No
108714	PC	24/07/2014	PC	Vehicles available	Acapulco	2013	Yes
108914	PC	24/07/2014	PC	Product inventory available per organisation	Acapulco	2013	No
108814	PC	24/07/2014	PC	Supply capacity	Acapulco	2013	No
108814	PC	24/07/2014	PC	Supply lead time	Acapulco	2013	Yes
109014	PC	24/07/2014	PC	Food pantries delivered	Acapulco	2013	Yes
109014	PC	24/07/2014	PC	Other items delivered	Acapulco	2013	Yes
109014	PC	24/07/2014	PC	Shipment diary	Acapulco	2013	No
109114	SEGOB	25/07/2014	SEGOB	Shelters used	Acapulco	2013	No
109214	SEGOB	25/07/2014	SEGOB	Shelter history per state	Acapulco	2013	No
109314	SEGOB	25/07/2014	SEGOB	Evolution of shelters over time	Acapulco	2013	No
109414	SEGOB	25/07/2014	SEGOB	DCs used	Acapulco	2013	No
109514	SEGOB	25/07/2014	SEGOB	Supply capacity	Acapulco	2013	No
109514	SEGOB	25/07/2014	SEGOB	Other items delivered	Acapulco	2013	No
137214	SEGOB	08/09/2014	SEGOB	Personnel and vehicles used per agency	Acapulco	2013	No
142214	PC	22/09/2014	PC	Personnel and vehicles used per agency	Acapulco	2013	No

On the other hand, requests involving Acapulco made to National governmental authorities can be seen on Table C.4. As can be noticed, many of the requests are repeated from table D.2 given the fact that the request is focusing on Mexico and/or the three case studies simultaneously.

Table C.4. National requests for Acapulco

Folio	Source	Enquiry date	Class	Content	Area	Outcome
0000400101914	SEGOB	02/04/2014	SEGOB	Lead time distribution in disasters	Mexico	Partially
0000400160314	SEGOB	25/06/2014	SEGOB	Medicines distributed	Acapulco, Villahermosa and Veracruz	Yes
0000700002514	SEDENA	06/01/2014	SEDENA	Transportation cost per vehicle per km	Mexico	Yes
0000700002614	SEDENA	06/01/2014	SEDENA	Available vehicles for relief distribution	Mexico	Yes
0000700002714	SEDENA	06/01/2014	SEDENA	Shelters and demand	Acapulco	Yes
0000700002814	SEDENA	06/01/2014	SEDENA	Vehicles used	Acapulco	Yes
0000700002914	SEDENA	06/01/2014	SEDENA	Personnel used and activities	Acapulco	Yes
0000700003014	SEDENA	06/01/2014	SEDENA	Cost per vehicle per km	Acapulco	Yes
0000700003114	SEDENA	06/01/2014	SEDENA	Aid shipments	Acapulco	Yes
0000700003214	SEDENA	06/01/2014	SEDENA	Personnel distribution for shelters	Mexico	Yes
0000700003314	SEDENA	06/01/2014	SEDENA	Personnel distribution for DCs	Mexico	No
0000700003614	SEDENA	06/01/2014	SEDENA	DCs used	Acapulco	Yes
0000700004914	SEDENA	06/01/2014	SEDENA	Distribution personnel	Mexico	Yes
0000700013014	SEDENA	15/01/2014	SEDENA	Cost healthcare centres	Mexico	No
0000700013214	SEDENA	15/01/2014	SEDENA	Cost healthcare centres used	Acapulco	No
0000700014414	SEDENA	17/01/2014	SEDENA	Headquarters used	Acapulco	No
0000700014714	SEDENA	17/01/2014	SEDENA	DN-III Plan	Mexico	Partially
0000700031214	SEDENA	14/02/2014	SEDENA	Available personnel and activities	Mexico	No
0000700031414	SEDENA	14/02/2014	SEDENA	Personnel used and activities	Acapulco	Partially
0000700031514	SEDENA	14/02/2014	SEDENA	Vehicles used	Acapulco	Yes
0000700031614	SEDENA	14/02/2014	SEDENA	Available personnel and activities	Acapulco	No
0000700031714	SEDENA	14/02/2014	SEDENA	Available vehicles	Acapulco	Yes

0001200006514	SMEXICO	06/01/2014	SMEXICO	Personnel used and activities	Acapulco	Yes
0001200006914	SMEXICO	06/01/2014	SMEXICO	Vehicles used	Acapulco	Yes
0001200007114	SMEXICO	06/01/2014	SMEXICO	Shelters used	Acapulco	No
0001200007614	SMEXICO	06/01/2014	SMEXICO	DCs used	Acapulco	No
0001200007814	SMEXICO	06/01/2014	SMEXICO	Healthcare facilities used	Acapulco	No
0001200008214	SMEXICO	06/01/2014	SMEXICO	Medicines distributed	Acapulco	Yes
0001200008314	SMEXICO	06/01/2014	SMEXICO	Required medicines per 100 people	Mexico	Yes
0001200021314	SMEXICO	15/01/2014	SMEXICO	Procedure manuals for healthcare centers	Mexico	No
0001200021614	SMEXICO	15/01/2014	SMEXICO	Cost Healthcare facilities	Acapulco	No
0001300004214	SEMAR	17/01/2014	SEMAR	Headquarters used	Acapulco	No
0064100439314	IMSS	14/02/2014	IMSS	Personnel used and activities	Acapulco	Yes
0064100439414	IMSS	14/02/2014	IMSS	Vehicles used	Acapulco	Yes
0064100439514	IMSS	14/02/2014	IMSS	Available personnel and activities	Acapulco	Partially
0064100439614	IMSS	14/02/2014	IMSS	Available vehicles	Acapulco	Partially
0413000000414	CENAPRED	06/01/2014	CENAPRED	Satellite images	Acapulco	Partially
0413000000714	CENAPRED	06/01/2014	CENAPRED	Technical reports	Acapulco	Partially
1236000003414	DIF	17/01/2014	DIF	Activity reports	Veracruz, Guerrero and Tabasco	Yes
1236000003514	DIF	17/01/2014	DIF	Operation manuals	Mexico	Partially
2015000000614	DICONSA	06/01/2014	DICONSA	Pre-positioned stock	Guerrero	Yes
2015000000914	DICONSA	06/01/2014	DICONSA	DCs used	Acapulco	Yes
2015000001214	DICONSA	06/01/2014	DICONSA	Vehicles used	Acapulco	Yes
2015000001514	DICONSA	06/01/2014	DICONSA	Personnel used and activities	Acapulco	Yes
2015000001614	DICONSA	06/01/2014	DICONSA	Holding cost	Mexico	No
2015000001714	DICONSA	06/01/2014	DICONSA	Cost per vehicle per km	Mexico	No
2015000003314	DICONSA	14/02/2014	DICONSA	Available personnel and activities	Acapulco	Yes
2015000003414	DICONSA	14/02/2014	DICONSA	Vehicles used	Acapulco	Yes
2015000003514	DICONSA	14/02/2014	DICONSA	Available vehicles	Acapulco	Yes

2015000003614	DICONSA	14/02/2014	DICONSA	Personnel used and activities	Acapulco	Yes
2015000007014	DICONSA	02/04/2014	DICONSA	Supply capacity	Mexico	Yes
2015000008113	DICONSA	10/07/2013	DICONSA	Price list for floods	Veracruz, Guerrero and Tabasco	Partially
2015000008213	DICONSA	10/07/2013	DICONSA	Pre-positioned stock	Veracruz, Guerrero and Tabasco	Yes
0064101318214	IMSS	28/05/2014	IMSS	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	Yes
1236000015714	DIF	28/05/2014	DIF	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0001200185714	SMEXICO	28/05/2014	SMEXICO	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0000400160214	SEGOB	28/05/2014	SEGOB	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0002000092414	SEDESOL	28/05/2014	SEDESOL	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0064101318414	IMSS	28/05/2014	IMSS	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
1236000015814	DIF	28/05/2014	DIF	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0001200185814	SMEXICO	28/05/2014	SMEXICO	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160314	SEGOB	28/05/2014	SEGOB	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Partially
0002000092514	SEDESOL	28/05/2014	SEDESOL	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092614	SEDESOL	28/05/2014	SEDESOL	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0000700097214	SEDENA	28/05/2014	SEDENA	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160414	SEGOB	28/05/2014	SEGOB	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
1236000015914	DIF	28/05/2014	DIF	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0001300043014	SEMAR	28/05/2014	SEMAR	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092714	SEDESOL	28/05/2014	SEDESOL	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0000700097314	SEDENA	28/05/2014	SEDENA	Shipment diary and lead time	Veracruz, Guerrero and Tabasco	No
0000400160514	SEGOB	28/05/2014	SEGOB	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
1236000016014	DIF	28/05/2014	DIF	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043114	SEMAR	28/05/2014	SEMAR	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043214	SEMAR	28/05/2014	SEMAR	Satellite images	Veracruz, Guerrero and Tabasco	Yes
0000400160614	SEGOB	28/05/2014	SEGOB	International aid	Veracruz, Guerrero and Tabasco	No
0000500088214	SRE	28/05/2014	SRE	International aid	Veracruz, Guerrero and Tabasco	YES

0001300043414	SEMAR	28/05/2014	SEMAR	Personnel used and activities	Acapulco	Yes
0002000093214	SEDESOL	28/05/2014	SEDESOL	Required shelter and DC personnel	Mexico	No
2015000010314	DICONSA	28/05/2014	DICONSA	Required shelter and DC personnel	Mexico	No
0001200186214	SMEXICO	28/05/2014	SMEXICO	Required shelter and DC personnel	Mexico	No
0001300043614	SEMAR	28/05/2014	SEMAR	Required shelter and DC personnel	Mexico	No
1236000016314	DIF	28/05/2014	DIF	Required shelter and DC personnel	Mexico	No
0001200186414	SMEXICO	28/05/2014	SMEXICO	Required healthcare personnel	Mexico	No
0064101320214	IMSS	28/05/2014	IMSS	Required healthcare personnel	Mexico	Yes
0002000093314	SEDESOL	28/05/2014	SEDESOL	Required personnel for distribution	Mexico	No
2015000010414	DICONSA	28/05/2014	DICONSA	Required personnel for distribution	Mexico	Yes
1236000016414	DIF	28/05/2014	DIF	Required personnel for distribution	Mexico	No
0000700104614	SEDENA	06/06/2014	SEDENA	Shelter history	Guerrero	Yes
0000700104714	SEDENA	07/06/2014	SEDENA	Monthly shelter demand	Acapulco	No
0000700113414	SEDENA	23/06/2014	SEDENA	DC capacity	Acapulco	Yes
0002000114814	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock currently	Acapulco, Villahermosa and Veracruz	No
0002000114914	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock used	Acapulco, Villahermosa and Veracruz	No
0001200234314	SMEXICO	11/07/2014	SMEXICO	Content of the disaster kit of medicines	Mexico	Yes
0001200249214	SMEXICO	24/07/2014	SMEXICO	Procurement per product	Acapulco	Yes
0001200249314	SMEXICO	24/07/2014	SMEXICO	Product inventory available per organisation	Acapulco	No
0001200249514	SMEXICO	24/07/2014	SMEXICO	Supply capacity	Acapulco	No
0001200249414	SMEXICO	24/07/2014	SMEXICO	Holding cost	Acapulco	No
0001200249614	SMEXICO	24/07/2014	SMEXICO	Shipment diary	Acapulco	Yes
0001300056914	SEMAR	24/07/2014	SEMAR	Vehicles used	Acapulco	Partially
0001300056914	SEMAR	24/07/2014	SEMAR	Vehicles available	Acapulco	No
0413000010014	CENAPRED	25/07/2014	CENAPRED	Technical reports	Acapulco	YES
2015000012814	DICONSA	25/07/2014	DICONSA	DCs available	Acapulco	No
2015000012814	DICONSA	25/07/2014	DICONSA	Capacities DCs available	Acapulco	No

2015000012814	DICONSA	25/07/2014	DICONSA	Fixed cost DCs	Acapulco	No
2015000012914	DICONSA	25/07/2014	DICONSA	Food pantries delivered	Acapulco	Yes
2015000012914	DICONSA	25/07/2014	DICONSA	Other items delivered	Acapulco	Yes
2015000013014	DICONSA	25/07/2014	DICONSA	Shipment diary	Acapulco	No
0064101758514	IMSS	25/07/2014	IMSS	Procurement per product	Acapulco	No
0064101758614	IMSS	25/07/2014	IMSS	Product inventory available per organisation	Acapulco	No
0064101758714	IMSS	25/07/2014	IMSS	Shipment diary	Acapulco	No
0000400233814	SEGOB	25/07/2014	SEGOB	Shelters used	Acapulco, Villahermosa and Veracruz	Partially
0000400233914	SEGOB	25/07/2014	SEGOB	Shelter history per state	Acapulco, Villahermosa and Veracruz	Yes
0000400234014	SEGOB	25/07/2014	SEGOB	Evolution of shelters over time	Acapulco, Villahermosa and Veracruz	No
0000400234114	SEGOB	25/07/2014	SEGOB	DCs used	Acapulco, Villahermosa and Veracruz	No
0000400234214	SEGOB	25/07/2014	SEGOB	Supply capacity	Acapulco, Villahermosa and Veracruz	No
0000400256014	SEGOB	25/07/2014	SEGOB	Other items delivered	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for DC	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for shelter	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for healthcare	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for distribution	Acapulco, Villahermosa and Veracruz	No
0000400265014	SEGOB	28/08/2014	SEGOB	Total personnel and vehicles used	Acapulco	No
0064102208814	IMSS	29/09/2014	IMSS	People sheltered	Acapulco	No

Villahermosa

From the different cases Villahermosa was the one with more agencies involved, yielding a larger number of requests overall and specially in the region. Tabasco has considerable experience with floods and different organisations get involved, so the number of these requests outnumbered the number of requests to National authorities. Starting with the information required form the former, Table C.5 shows the summary of enquiries filed to regional authorities about the activities carried out on the flood of 2007 in Villahermosa.

About the results some organisations claimed not to have jurisdiction or information available, which was reflected on the list as an outcome of “No”, whereas “Yes” was used when the information was satisfactory and “Partially” when the information was indirectly reflecting what was required. The folio is the number adhered to the request, the source the organisation enquired, the date for recording purposes, the class includes the folder in the storage drive, the content highlights the purpose of the request and the area describes the region of interest.

Table C.5. Regional enquiries for the case of Villahermosa

Folio	Source	Enquiry date	Class	Content	Area	Outcome
5086313	SSP	16/09/2013	SSP	Shelters used	Villahermosa	NO
5086413	CENTRO	16/09/2013	CENTRO	Shelters used	Villahermosa	NO
5114413	SEGOB	16/09/2013	SEGOB	Shelters used	Villahermosa	NO
5114713	SEGOB	16/09/2013	SEGOB	DCs used	Villahermosa	NO
5114813	SEGOB	16/09/2013	SEGOB	Reports from the flood	Villahermosa	NO
5115013	CENTRO	16/09/2013	CENTRO	DCs used	Villahermosa	NO
5115113	SEGOB	27/08/2013	SEGOB	Shelter cost	Villahermosa	NO
5133713	DIF	27/08/2013	DIF	Shelter cost	Villahermosa	NO
5133813	DIF	27/08/2013	DIF	Evolution shelters over time	Villahermosa	NO
5922414	SSP	19/03/2014	SSP	Personnel used	Villahermosa	NO
5922514	SSP	19/03/2014	SSP	Personnel used	Villahermosa	NO
5922614	SSP	19/03/2014	SSP	Vehicles used	Villahermosa	NO
5922714	SSP	19/03/2014	SSP	Personnel available	Villahermosa	NO
5922814	SSP	19/03/2014	SSP	Vehicles available	Villahermosa	NO
5922914	CENTRO	14/03/2014	CENTRO	Shelter personnel used	Villahermosa	NO
5923014	CENTRO	02/04/2014	CENTRO	Vehicles used	Villahermosa	YES
5923114	CENTRO	01/04/2014	CENTRO	Available personnel	Villahermosa	NO
5923214	CENTRO	01/04/2014	CENTRO	Vehicles available	Villahermosa	YES
5923314	SEDESOL	01/04/2014	SEDESOL	Personnel used	Villahermosa	NO
5923414	SEDESOL	01/04/2014	SEDESOL	Vehicles used	Villahermosa	NO
5923514	SEDESOL	01/04/2014	SEDESOL	Personnel available	Villahermosa	NO

5923614	SEDESOL	01/04/2014	SEDESOL	Vehicles available	Villahermosa	NO
5923714	STABASCO	01/04/2014	STABASCO	Personnel used	Villahermosa	YES
5923814	STABASCO	01/04/2014	STABASCO	Vehicles used	Villahermosa	YES
5923914	STABASCO	01/04/2014	STABASCO	Personnel available	Villahermosa	YES
5924014	STABASCO	01/04/2014	STABASCO	Vehicles available	Villahermosa	YES
5924114	SSP	01/04/2014	SSP	Personnel used	Villahermosa	NO
5924214	SSP	01/04/2014	SSP	Vehicles used	Villahermosa	NO
5924314	SSP	01/04/2014	SSP	Personnel available	Villahermosa	YES
5924414	SSP	01/04/2014	SSP	Vehicles available	Villahermosa	YES
5924714	SCT	01/04/2014	SCT	Vehicles used	Villahermosa	NO
5924814	SCT	01/04/2014	SCT	Personnel used	Villahermosa	NO
5924914	SCT	01/04/2014	SCT	Vehicles used	Villahermosa	NO
5925014	SCT	01/04/2014	SCT	Personnel available	Villahermosa	NO
6241514	DIF	13/06/2014	DIF	Number of shelters	Tabasco	NO
6241714	CENTRO	13/06/2014	CENTRO	Number of shelters	Tabasco	NO
6241814	Universidad	13/06/2014	Universidad	Number of shelters	Tabasco	NO
6241914	STABASCO	13/06/2014	STABASCO	Number of shelters	Tabasco	NO
6242014	DIF	13/06/2014	DIF	Shelter history	Villahermosa	NO
6242114	CENTRO	13/06/2014	CENTRO	Shelter history	Villahermosa	NO
6242214	Universidad	13/06/2014	Universidad	Shelter history	Villahermosa	NO
6242314	STABASCO	13/06/2014	STABASCO	Shelter history	Villahermosa	NO
6242414	SSP	13/06/2014	SSP	Shelter history	Villahermosa	NO
6242514	STABASCO	13/06/2014	STABASCO	Required Healthcare personnel	Tabasco	NO
6242714	SEGOB	13/06/2014	SEGOB	Number of shelters	Tabasco	YES
6242814	SEGOB	13/06/2014	SEGOB	Shelter history	Villahermosa	NO
6242914	DIF	13/06/2014	DIF	Required distribution personnel	Tabasco	NO
6243014	STABASCO	13/06/2014	STABASCO	Required distribution personnel	Tabasco	NO

6243114	SSP	13/06/2014	SSP	Required distribution personnel	Tabasco	NO
6243214	DIF	13/06/2014	DIF	CDs used	Villahermosa	NO
6243314	SEDESOL	13/06/2014	SEDESOL	CDs used	Villahermosa	NO
6243414	CENTRO	13/06/2014	CENTRO	DC personnel used	Villahermosa	NO
6243514	CENTRO	13/06/2014	CENTRO	Healthcare personnel used	Villahermosa	NO
6243614	CENTRO	13/06/2014	CENTRO	Distribution personnel used	Villahermosa	NO
6243714	SCT	13/06/2014	SCT	DC personnel used	Villahermosa	YES
6243814	SCT	13/06/2014	SCT	Healthcare personnel used	Villahermosa	NO
6243914	SCT	13/06/2014	SCT	Distribution personnel used	Villahermosa	NO
6399414	DIF	25/07/2014	DIF	Shelters used	Villahermosa	NO
6399414	DIF	25/07/2014	DIF	Shelter capacity	Villahermosa	NO
6399514	DIF	25/07/2014	DIF	DCs used	Villahermosa	NO
6399514	DIF	25/07/2014	DIF	DC capacity	Villahermosa	NO
6399614	DIF	25/07/2014	DIF	Fixed cost DCs	Villahermosa	NO
6399714	DIF	25/07/2014	DIF	Fixed cost shelters	Villahermosa	NO
6399914	DIF	25/07/2014	DIF	Available agency personnel for DC	Villahermosa	YES
6399914	DIF	25/07/2014	DIF	Available agency personnel for shelter	Villahermosa	YES
6399914	DIF	25/07/2014	DIF	Available agency personnel for distribution	Villahermosa	YES
6399814	DIF	25/07/2014	DIF	Used agency personnel for DC	Villahermosa	NO
6399814	DIF	25/07/2014	DIF	Used agency personnel for shelter	Villahermosa	NO
6399814	DIF	25/07/2014	DIF	Used agency personnel for distribution	Villahermosa	NO
6399814	DIF	25/07/2014	DIF	Total personnel per agency	Villahermosa	YES
6400014	DIF	25/07/2014	DIF	Vehicles used	Villahermosa	NO
6400114	DIF	25/07/2014	DIF	Vehicles available	Villahermosa	YES
06400214	STABASCO	25/07/2014	STABASCO	Shelters used	Villahermosa	NO
06400214	STABASCO	25/07/2014	STABASCO	Shelter capacity	Villahermosa	NO
06400314	STABASCO	25/07/2014	STABASCO	Procurement per product	Villahermosa	YES

06400414	STABASCO	25/07/2014	STABASCO	Required personnel for healthcare	Villahermosa	YES
06400514	STABASCO	25/07/2014	STABASCO	Product inventory available per organisation	Villahermosa	YES
06400614	STABASCO	25/07/2014	STABASCO	Supply capacity	Villahermosa	YES
06400614	STABASCO	25/07/2014	STABASCO	Supply lead time	Villahermosa	YES
06400714	STABASCO	25/07/2014	STABASCO	Medicines delivered	Villahermosa	YES
06400714	STABASCO	25/07/2014	STABASCO	Shipment diary	Villahermosa	YES
06400814	SEDESOL	25/07/2014	SEDESOL	Procurement per product	Villahermosa	NO
06400914	ISSET	25/07/2014	ISSET	Shelters available	Villahermosa	YES
06400914	ISSET	25/07/2014	ISSET	Shelters used	Villahermosa	YES
06400914	ISSET	25/07/2014	ISSET	Shelter capacity	Villahermosa	YES
06644914	ISSET	25/07/2014	ISSET	Healthcare personnel used	Villahermosa	YES
06645214	ISSET	25/07/2014	ISSET	Vehicles used	Villahermosa	NO
06645014	ISSET	25/07/2014	ISSET	Product inventory available per organisation	Villahermosa	NO
06645114	ISSET	25/07/2014	ISSET	Shipment diary	Villahermosa	NO
06401414	CENTRO	25/07/2014	CENTRO	Shelters available	Villahermosa	NO
06401414	CENTRO	25/07/2014	CENTRO	Shelters used	Villahermosa	NO
06401414	CENTRO	25/07/2014	CENTRO	Shelter capacity	Villahermosa	NO
06401414	CENTRO	25/07/2014	CENTRO	Evolution of shelters over time	Villahermosa	NO
06401514	CENTRO	25/07/2014	CENTRO	DCs available	Villahermosa	NO
06401514	CENTRO	25/07/2014	CENTRO	DCs used	Villahermosa	NO
06401514	CENTRO	25/07/2014	CENTRO	DC capacity	Villahermosa	NO
06401714	CENTRO	25/07/2014	CENTRO	Fixed cost DCs	Villahermosa	NO
06401814	CENTRO	25/07/2014	CENTRO	Fixed cost shelters	Villahermosa	NO
06401614	CENTRO	25/07/2014	CENTRO	Food pantries delivered	Villahermosa	NO
06401614	CENTRO	25/07/2014	CENTRO	Other products delivered	Villahermosa	NO
06401914	PC	25/07/2014	SEGOB	Shelters available	Villahermosa	YES
06401914	PC	25/07/2014	SEGOB	Shelters used	Villahermosa	YES

06401914	PC	25/07/2014	SEGOB	Shelter capacity	Villahermosa	YES
06402214	PC	25/07/2014	SEGOB	Shelter history per state	Villahermosa	NO
06401914	PC	25/07/2014	SEGOB	Evolution of shelters over time	Villahermosa	NO
06402014	PC	25/07/2014	SEGOB	DCs available	Villahermosa	YES
06402014	PC	25/07/2014	SEGOB	DCs used	Villahermosa	YES
06402014	PC	25/07/2014	SEGOB	DC capacity	Villahermosa	YES
06402414	PC	25/07/2014	SEGOB	Fixed cost DCs	Villahermosa	NO
06402314	PC	25/07/2014	SEGOB	Fixed cost shelters	Villahermosa	NO
06402714	PC	25/07/2014	SEGOB	Required personnel per shelter	Villahermosa	NO
06402714	PC	25/07/2014	SEGOB	Required personnel per DC	Villahermosa	NO
06402714	PC	25/07/2014	SEGOB	Required personnel for healthcare	Villahermosa	NO
06402714	PC	25/07/2014	SEGOB	Required personnel for distribution	Villahermosa	NO
06402514	PC	25/07/2014	SEGOB	Available agency personnel for DC	Villahermosa	NO
06402514	PC	25/07/2014	SEGOB	Available agency personnel for shelter	Villahermosa	NO
06402514	PC	25/07/2014	SEGOB	Available agency personnel for healthcare	Villahermosa	NO
06402514	PC	25/07/2014	SEGOB	Available agency personnel for distribution	Villahermosa	NO
06402614	PC	25/07/2014	SEGOB	Used agency personnel for DC	Villahermosa	NO
06402614	PC	25/07/2014	SEGOB	Used agency personnel for shelter	Villahermosa	NO
06402614	PC	25/07/2014	SEGOB	Used agency personnel for healthcare	Villahermosa	NO
06402614	PC	25/07/2014	SEGOB	Used agency personnel for distribution	Villahermosa	NO
06402614	PC	25/07/2014	SEGOB	Total personnel per agency	Villahermosa	YES
06402814	PC	25/07/2014	SEGOB	Vehicles used	Villahermosa	YES
06402814	PC	25/07/2014	SEGOB	Vehicles available	Villahermosa	YES
06403014	PC	25/07/2014	SEGOB	Product inventory available per organisation	Villahermosa	NO
06402914	PC	25/07/2014	SEGOB	Supply capacity	Villahermosa	NO
06402914	PC	25/07/2014	SEGOB	Supply lead time	Villahermosa	YES
06402114	PC	25/07/2014	SEGOB	Food pantries delivered	Villahermosa	NO

06402114	PC	25/07/2014	SEGOB	Other products delivered	Villahermosa	NO
06403114	PC	25/07/2014	SEGOB	Shipment diary	Villahermosa	NO
06645414	SEGOB	28/08/2014	SEGOB	Available shelters	Villahermosa	YES
06645514	SEGOB	28/08/2014	SEGOB	Personnel and vehicles per agency	Villahermosa	NO
06689714	SEGOB	08/09/2014	SEGOB	Personnel and vehicles used	Villahermosa	NO

Finally, Table C.6 exhibits details about enquiries focusing mostly on National standards or in specific requests about the disaster in the area from National authorities. As can be expected, there are overlaps between some of these requests and the requests performed to National authorities in previous cases.

Table C.6. National enquiries for the case of Villahermosa

Folio	Source	Enquiry date	Class	Content	Area	Outcome
0000400101914	SEGOB	02/04/2014	SEGOB	Lead time distribution in disasters	Mexico	Partially
0000400160314	SEGOB	25/06/2014	SEGOB	Medicines distributed	Acapulco, Villahermosa and Veracruz	Yes
0000400173913	SEGOB	10/07/2013	SEGOB	Shelters and DCs	Villahermosa	No
0000400174213	SEGOB	10/07/2013	SEGOB	Shelters, demand, vehicles, people	Villahermosa	No
0000400174513	SEGOB	10/07/2013	SEGOB	Cost shelters and Dcs, final reports	Villahermosa	No
0000700002514	SEDENA	06/01/2014	SEDENA	Transportation cost per vehicle per lm	Mexico	Yes
0000700002614	SEDENA	06/01/2014	SEDENA	Type and number of available vehicles for relief distribution	Mexico	Yes
0000700003214	SEDENA	06/01/2014	SEDENA	Personnel distribution for shelters	Mexico	Yes
0000700003314	SEDENA	06/01/2014	SEDENA	Personnel distribution for DCs	Mexico	No
0000700003414	SEDENA	06/01/2014	SEDENA	DCs used	Villahermosa	Yes
0000700004914	SEDENA	06/01/2014	SEDENA	Distribution personnel	Mexico	Yes
0000700013014	SEDENA	15/01/2014	SEDENA	Cost healthcare centres	Mexico	No
0000700014514	SEDENA	17/01/2014	SEDENA	Headquarters used	Villahermosa	No
0000700014614	SEDENA	17/01/2014	SEDENA	Headquarters used	Villahermosa	No
0000700014714	SEDENA	17/01/2014	SEDENA	DN-III Plan	Mexico	Partially

0000700031014	SEDENA	14/02/2014	SEDENA	Personnel used and activities	Villahermosa	Partially
0000700031114	SEDENA	14/02/2014	SEDENA	Vehicles used	Villahermosa	Partially
0000700031214	SEDENA	14/02/2014	SEDENA	Available personnel and activities	Mexico	No
0000700031314	SEDENA	14/02/2014	SEDENA	Available vehicles	Villahermosa	Yes
0000700106513	SEDENA	10/07/2013	SEDENA	Shelters, demand, personnel and vehicles	Villahermosa	Yes
0001200006714	SMEXICO	06/01/2014	SMEXICO	Personnel used and activities	Villahermosa	Yes
0001200006814	SMEXICO	06/01/2014	SMEXICO	Vehicles used	Villahermosa	Yes
0001200007214	SMEXICO	06/01/2014	SMEXICO	Shelters used	Villahermosa	No
0001200007414	SMEXICO	06/01/2014	SMEXICO	DCs used	Villahermosa	No
0001200007714	SMEXICO	06/01/2014	SMEXICO	Healthcare facilities used	Villahermosa	No
0001200008014	SMEXICO	06/01/2014	SMEXICO	Medicines distributed	Villahermosa	No
0001200008314	SMEXICO	06/01/2014	SMEXICO	Required medicines per 100 people	Mexico	Yes
0001200021314	SMEXICO	15/01/2014	SMEXICO	Procedure manuals for healthcare centres	Mexico	No
0001200021414	SMEXICO	15/01/2014	SMEXICO	Cost Healthcare facilities	Villahermosa	No
0001300004114	SEMAR	17/01/2014	SEMAR	Headquarters used	Villahermosa	No
0001300051013	SEMAR	10/07/2013	SEMAR	Vehicles used and cost per km per vehicle	Villahermosa	Partially
0064100438914	IMSS	14/02/2014	IMSS	Personnel used and activities	Villahermosa	Yes
0064100439014	IMSS	14/02/2014	IMSS	Vehicles used	Villahermosa	Yes
0064100439114	IMSS	14/02/2014	IMSS	Available personnel and activities	Villahermosa	Partially
0064100439214	IMSS	14/02/2014	IMSS	Available vehicles	Villahermosa	Partially
0413000000214	CENAPRED	06/01/2014	CENAPRED	Satellite images	Villahermosa	Partially
0413000000514	CENAPRED	06/01/2014	CENAPRED	Technical reports	Villahermosa	Partially
1236000003414	DIF	17/01/2014	DIF	Activity reports	Veracruz, Guerrero and Tabasco	Yes
1236000003514	DIF	17/01/2014	DIF	Operation manuals	Mexico	Partially
2015000000714	DICONSA	06/01/2014	DICONSA	DCs used	Villahermosa	Yes
2015000001014	DICONSA	06/01/2014	DICONSA	Vehicles used	Villahermosa	Yes
2015000001314	DICONSA	06/01/2014	DICONSA	Personnel used and activities	Villahermosa	Yes

2015000001614	DICONSA	06/01/2014	DICONSA	Holding cost	Mexico	No
2015000001714	DICONSA	06/01/2014	DICONSA	Cost per vehicle per km	Mexico	No
2015000003714	DICONSA	14/02/2014	DICONSA	Available vehicles	Villahermosa	Yes
2015000003814	DICONSA	14/02/2014	DICONSA	Available personnel and activities	Villahermosa	Yes
2015000003914	DICONSA	14/02/2014	DICONSA	Vehicles used	Villahermosa	Yes
2015000004014	DICONSA	14/02/2014	DICONSA	Personnel used and activities	Villahermosa	Yes
2015000007014	DICONSA	02/04/2014	DICONSA	Supply capacity	Mexico	Yes
2015000008113	DICONSA	10/07/2013	DICONSA	Price list for floods	Veracruz, Guerrero and Tabasco	On revision resource partially
2015000008213	DICONSA	10/07/2013	DICONSA	Pre-positioned stock	Veracruz, Guerrero and Tabasco	Yes
0064101318214	IMSS	28/05/2014	IMSS	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	Yes
1236000015714	DIF	28/05/2014	DIF	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0001200185714	SMEXICO	28/05/2014	SMEXICO	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0000400160214	SEGOB	28/05/2014	SEGOB	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0002000092414	SEDESOL	28/05/2014	SEDESOL	Lead time and supply capacity for medicines	Veracruz, Guerrero and Tabasco	No
0064101318414	IMSS	28/05/2014	IMSS	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
1236000015814	DIF	28/05/2014	DIF	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0001200185814	SMEXICO	28/05/2014	SMEXICO	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160314	SEGOB	28/05/2014	SEGOB	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	Partially
0002000092514	SEDESOL	28/05/2014	SEDESOL	Medicines distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092614	SEDESOL	28/05/2014	SEDESOL	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0000700097214	SEDENA	28/05/2014	SEDENA	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	Yes
0000400160414	SEGOB	28/05/2014	SEGOB	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
1236000015914	DIF	28/05/2014	DIF	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0001300043014	SEMAR	28/05/2014	SEMAR	Relief items distributed and stock	Veracruz, Guerrero and Tabasco	No
0002000092714	SEDESOL	28/05/2014	SEDESOL	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0000700097314	SEDENA	28/05/2014	SEDENA	Shipment diary and lead time	Veracruz, Guerrero and Tabasco	No
0000400160514	SEGOB	28/05/2014	SEGOB	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No

1236000016014	DIF	28/05/2014	DIF	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043114	SEMAR	28/05/2014	SEMAR	Shipment diary and lead dime	Veracruz, Guerrero and Tabasco	No
0001300043214	SEMAR	28/05/2014	SEMAR	Satellite images	Veracruz, Guerrero and Tabasco	Yes
0000400160614	SEGOB	28/05/2014	SEGOB	International aid	Veracruz, Guerrero and Tabasco	No
0000500088214	SRE	28/05/2014	SRE	International aid	Veracruz, Guerrero and Tabasco	YES
0002000093214	SEDESOL	28/05/2014	SEDESOL	Required shelter and DC personnel	Mexico	No
2015000010314	DICONSA	28/05/2014	DICONSA	Required shelter and DC personnel	Mexico	No
0001200186214	SMEXICO	28/05/2014	SMEXICO	Required shelter and DC personnel	Mexico	No
0001300043614	SEMAR	28/05/2014	SEMAR	Required shelter and DC personnel	Mexico	No
1236000016314	DIF	28/05/2014	DIF	Required shelter and DC personnel	Mexico	No
0001200186414	SMEXICO	28/05/2014	SMEXICO	Required healthcare personnel	Mexico	No
0064101320214	IMSS	28/05/2014	IMSS	Required healthcare personnel	Mexico	Yes
0002000093314	SEDESOL	28/05/2014	SEDESOL	Required personnel for distribution	Mexico	No
2015000010414	DICONSA	28/05/2014	DICONSA	Required personnel for distribution	Mexico	Yes
1236000016414	DIF	28/05/2014	DIF	Required personnel for distribution	Mexico	No
0002000114814	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock currently	Acapulco, Villahermosa and Veracruz	No
0002000114914	SEDESOL	01/07/2014	SEDESOL	Pre-positioned stock used	Acapulco, Villahermosa and Veracruz	No
0001200234314	SMEXICO	11/07/2014	SMEXICO	Content of the disaster kit of medicines	Mexico	Yes
0001200249214	SMEXICO	25/07/2014	SMEXICO	Procurement per product	Villahermosa	Yes
0001200249814	SMEXICO	25/07/2014	SMEXICO	Available agency personnel for healthcare	Villahermosa	No
0001200249814	SMEXICO	25/07/2014	SMEXICO	Used agency personnel for healthcare	Villahermosa	No
0001200249314	SMEXICO	25/07/2014	SMEXICO	Product inventory available per organisation	Villahermosa	No
0001200249414	SMEXICO	25/07/2014	SMEXICO	Supply capacity	Villahermosa	No
0001200249614	SMEXICO	25/07/2014	SMEXICO	Shipment diary	Villahermosa	No
0000700144114	SEDENA	25/07/2014	SEDENA	Shelters available	Villahermosa	No
0000700144114	SEDENA	25/07/2014	SEDENA	Shelter capacity	Villahermosa	No
0000700144214	SEDENA	25/07/2014	SEDENA	DCs available	Villahermosa	Yes

0000700144214	SEDENA	25/07/2014	SEDENA	DC capacity	Villahermosa	No
0000700144314	SEDENA	25/07/2014	SEDENA	Used agency personnel for DC	Villahermosa	No
0000700144314	SEDENA	25/07/2014	SEDENA	Used agency personnel for shelter	Villahermosa	No
0000700144314	SEDENA	25/07/2014	SEDENA	Used agency personnel for healthcare	Villahermosa	No
0000700144314	SEDENA	25/07/2014	SEDENA	Used agency personnel for distribution	Villahermosa	No
0000700144414	SEDENA	25/07/2014	SEDENA	Shipment diary	Villahermosa	No
0001300057014	SEMAR	25/07/2014	SEMAR	Used agency personnel for DC	Villahermosa	No
0001300057014	SEMAR	25/07/2014	SEMAR	Used agency personnel for shelter	Villahermosa	No
0001300057014	SEMAR	25/07/2014	SEMAR	Used agency personnel for distribution	Villahermosa	No
0001300057014	SEMAR	25/07/2014	SEMAR	Total personnel per agency	Villahermosa	No
2015000012814	DICONSA	24/07/2014	DICONSA	Fixed cost DCs	Villahermosa	No
2015000012914	DICONSA	25/07/2014	DICONSA	Food pantries delivered	Villahermosa	Yes
2015000012914	DICONSA	25/07/2014	DICONSA	Other products delivered	Villahermosa	Yes
2015000013014	DICONSA	25/07/2014	DICONSA	Shipment diary	Villahermosa	No
0000400233814	SEGOB	25/07/2014	SEGOB	Shelters used	Acapulco, Villahermosa and Veracruz	Partially
0000400233914	SEGOB	25/07/2014	SEGOB	Shelter history per state	Acapulco, Villahermosa and Veracruz	Yes
0000400234014	SEGOB	25/07/2014	SEGOB	Evolution of shelters over time	Acapulco, Villahermosa and Veracruz	No
0000400234114	SEGOB	25/07/2014	SEGOB	DCs used	Acapulco, Villahermosa and Veracruz	2007, 2010, 2013
0000400234214	SEGOB	25/07/2014	SEGOB	Supply capacity	Acapulco, Villahermosa and Veracruz	No
0000400256014	SEGOB	25/07/2014	SEGOB	Other items delivered	Acapulco, Villahermosa and Veracruz	2007, 2010, 2013
0064101759514	IMSS	25/07/2014	IMSS	Shelters available	Villahermosa	No
0064101759514	IMSS	25/07/2014	IMSS	Shelters used	Villahermosa	No
0064101759514	IMSS	25/07/2014	IMSS	Shelter capacity	Villahermosa	No
0064101759614	IMSS	25/07/2014	IMSS	Procurement per product	Villahermosa	No
0064101759814	IMSS	25/07/2014	IMSS	Product inventory available per organisation	Villahermosa	No
0064101759914	IMSS	25/07/2014	IMSS	Shipment diary	Villahermosa	No

0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for DC	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for shelter	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for healthcare	Acapulco, Villahermosa and Veracruz	No
0000400256414	SEGOB	20/08/2014	SEGOB	Used agency personnel for distribution	Acapulco, Villahermosa and Veracruz	No
0000400264914	SEGOB	28/08/2014	SEGOB	Total personnel and vehicles used	Villahermosa	No
0000400329214	SEGOB	16/10/2014	SEGOB	Shelter history	Tabasco	

Appendix D. Available facilities used for the case studies

Veracruz

Elaborating on the facilities included on the case studies, Table D.1 includes the list of the shelters available for the analysis in Veracruz along with the calculations for capacity and cost described on Section 6.1.3.1.

Table D.1. Shelters available in Veracruz

ID	Name	Address	Area	Indoors area	Capacity	Storage capacity	Cleaning cost	Mat cost	Blanket cost	Flashlight cost	Raincoat cost	Container cost	Bathtubs cost	Location cost (MXN)
1	World Trade Center	Blvb. Adolfo Ruiz Cortines 3497	20000	12000	3429	1714	29006.6	236571.4	123428.6	61275.5	284571.4	38762.1	9765.0	783380.7
2	Club de Leones	ARISTA NO. 3247 COL. MIGUEL HIDALGO	1000	600	171	85.5	1450.3	11828.6	6171.4	3003.0	14228.6	1899.7	558.0	39139.6
3	Cuartel de la VI región militar	Paseo Ejercito Mexicano Poniente S/N	10080	6048	1728	864	14619.4	119232.0	62208.0	30888.0	143424.0	19539.4	5022.0	394932.7
4	DIF-Municipal	Av. Matamoros S/N, Fraccionamiento Los Pinos	484	290.4	83	41	702.0	5725.0	2987.0	1430.0	6886.6	904.6	279.0	18914.2
5	Auditorio Benito Juárez	Av. Miguel Aleman esq. Calle Tuero Molina	4488	2692.8	769	384.5	6509.1	53086.6	27697.4	13728.0	63857.8	8684.2	2232.0	175795.1
6	Instituto Veracruzano del Deporte	Calle Alaminios, Virginia	4824	2894.4	827	413	6996.4	57061.0	29771.0	14729.0	68638.6	9317.4	2511.0	189024.4
7	PRIMARIA MéXICO	CONSTITUCIÓN ESQ. REVILLAGIGEDO COL. MéXICO	1689	1013.4	290	144.5	2449.6	19978.5	10423.5	5148.0	24032.1	3256.6	837.0	66125.2
8	ESCUELA JULIO S. MONTERO	REVILLAGIGEDO NO. 2049 ESQ. CANAL CENTRO	1380	828	237	118	2001.5	16323.4	8516.6	4218.5	19635.4	2668.6	837.0	54201.0
9	ESCUELA CONSTANZA CONDES DE LA TORRE	MIGUEL ÁNGEL DE QUEVEDO NO. 6118 ESQ. CUAUHTéMOC COL. ORTIZ RUBIO	746	447.6	128	63.5	1081.9	8824.1	4603.9	2216.5	10614.5	1402.1	558.0	29301.1
10	ESCUELA ADALBERTO TEJEDA	CAMPERO NO. 202 ESQ. NETZAHUALCOYOLT	465	279	80	39.5	674.4	5500.3	2869.7	1358.5	6616.3	859.4	279.0	18157.6
11	ESCUELA SALVADOR DÍAZ MIRÓN	JUAN ENRÍQUEZ NO. 1030 ENTRE DÍAZ MIRÓN Y LA FRAGUA	800	480	137	68.5	1160.3	9462.9	4937.1	2431.0	11382.9	1537.8	558.0	31469.9
12	ESCUELA GRAL. HERIBERTO JARA	ECHEVEN NO. 203 ESQ. ALLENDE Y NETZAHUALCOYOLT CENTRO	546	327.6	94	46.5	791.9	6458.4	3369.6	1644.5	7768.8	1040.3	279.0	21352.5
13	ESCUELA JUSTINO SARMIENTO	REVILLAGIGEDO NO. 2571 ENTRE CANAL Y CORTES COL. CENTRO	569	341.4	98	48.5	825.2	6730.5	3511.5	1716.0	8096.1	1085.5	279.0	22243.8
14	ESCUELA LEYES DE REFORMA	SIERRA GURUPI S/N INFONAVIT LAS BRISAS	1722	1033.2	295	147.5	2497.5	20368.8	10627.2	5219.5	24501.6	3301.8	837.0	67353.4
15	ESCUELA SECUNDARIA GENERAL NUM.5	CABO BASCUNAN Y CABO DE HORNOS	2310	1386	396	198	3350.3	27324.0	14256.0	7078.5	32868.0	4477.8	1116.0	90470.5
16	ESCUELA SOLIDARIDAD	RÍO LERMA S/N ENTRE RÍO MAYO Y RÍO YAQUI INFONAVIT RÍO MEDIO	1248	748.8	214	106.5	1810.0	14762.1	7701.9	3789.5	17757.3	2397.2	837.0	49055.0

17	ESCUELA ROSAURA ZAPATA CANO	SOL PONIENTE S/N COL. VISTA MAR	329	197.4	56	28	477.2	3891.6	2030.4	1001.0	4681.2	633.2	279.0	12993.6
18	ESC. JAIME TORRES BODET	CALLE 14 ESQ. ECHEVEN COL. POCITOS Y RIVERA	2468	1480.8	423	211.5	3579.4	29192.9	15231.1	7507.5	35116.1	4749.2	1395.0	96771.2
19	ESCUELA NICOLÁS BRAVO	EJE 1 SUR S/N ESQ. LAGUNA DE MANDINGA U.H. EL COYOL	798	478.8	137	68	1157.4	9439.2	4924.8	2431.0	11354.4	1537.8	558.0	31402.6
20	ESCUELA RICARDO FLORES MAGON	OAXACA NO. 1 ESQ. ORIZABA COL. VILLA DE GUADALUPE	438	262.8	75	37.5	635.2	5180.9	2703.1	1287.0	6232.1	814.1	279.0	17131.5
21	ESCUELA 1º DE MAYO	CONSTITUYENTES SUR ESQ. PUESTA DEL SOL	1460	876	250	125	2117.5	17269.7	9010.3	4433.0	20773.7	2804.3	837.0	57245.5
22	ESCUELA MUNICIPAL DE BELLAS ARTES	WASHINGTON 253 FRACC REFORMA	400	240	69	34	580.1	4731.4	2468.6	1215.5	5691.4	768.9	279.0	15735.0
23	ESCUELA VERACRUZANA DE DANZA	CANAL ESQ. ZARAGOZA S/N	730	438	125	62.5	1058.7	8634.9	4505.1	2216.5	10386.9	1402.1	558.0	28762.2
24	CENTRO DE ESTUDIOS TECNOLOGICOS DEL MAR	GRAL.FIGUEROA Y CANAL APDO P.246	4150	2490	711	355.5	6018.9	49088.6	25611.4	12655.5	59048.6	8005.7	2232.0	162660.7
25	CETIS 15	TULIPANES 141 U.HABIT.RUIZ C.	2590	1554	444	222	3756.4	30636.0	15984.0	7936.5	36852.0	5020.5	1395.0	101580.4
26	ESCUELA SECUNDARIA GENERAL P/TRABAJADORES	FRAMBOYANES 205 INFONAVIT B.VIST	1872	1123.2	321	160	2715.0	22143.1	11552.9	5720.0	26635.9	3618.4	1116.0	73501.3
27	ESC.NORMAL.SUP.FED. P/CURSOS INTENS EN VER	BOULEVARD ADOLFO RUIZ CORTINES S/N - S/N FRACCIONAMIENTO COSTA VERDE	4710	2826	807	403.5	6831.1	55712.6	29067.4	14371.5	67016.6	9091.2	2511.0	184601.4
28	CONALEP 1	PASEO FLORESTA ORIENTE 30 ESQUINA BAHAMAS, FRACCIONAMIENTO FLORESTA	3003	1801.8	515	257	4355.3	35521.2	18532.8	9152.0	42728.4	5789.4	1674.0	117753.2
29	CONALEP 144	PROL. CUAUHTEMOC S/N Y VERDUZCO	1622	973.2	278	139	2352.4	19185.9	10010.1	4933.5	23078.7	3120.9	837.0	63518.6
30	CENTRO ESCOLAR LIBERTAD	NETZAHUALCOYOTL 2254	1250	750	214	107	1812.9	14785.7	7714.3	3789.5	17785.7	2397.2	837.0	49122.3
31	COLEGIO HISPANO MEXICANO	ALACIO PEREZ 421	912	547.2	156	78	1322.7	10787.7	5628.3	2788.5	12976.5	1764.0	558.0	35825.6
33	COLEGIO OLLIMANI	SIMON BOLIVAR # 1033	540	324	93	46	783.2	6387.4	3332.6	1644.5	7683.4	1040.3	279.0	21150.4
34	COLEGIO PREPARATORIO MIGUEL ALEMAN	GOMEZ FARIAS NO. 1773	1380	828	237	118	2001.5	16323.4	8516.6	4218.5	19635.4	2668.6	837.0	54201.0
35	COLEGIO LA PAZ DE VERACRUZ A.C.	ALMACINGO NUM.87	5179	3107.4	888	443.5	7511.3	61260.2	31961.8	15801.5	73689.8	9995.8	2511.0	202731.4
36	COLEGIO IGNACIO MANUEL ALTAMIRANO	PROLONGACION DE DIAZ MIRON KM.3.5	570	342	98	48.5	826.7	6742.3	3517.7	1716.0	8110.3	1085.5	279.0	22277.5
37	COLEGIO DAVID P. WEIKART	CALLE REVILLAGIGEDO # 2770	1125	675	193	96	1631.6	13307.1	6942.9	3432.0	16007.1	2171.0	558.0	44049.8
38	CENTRO DE EDUCACION INFANTIL PAIDOS	20 DE NOV. 3037 FRACC. REFORMA.	750	450	129	64	1087.7	8871.4	4628.6	2288.0	10671.4	1447.4	558.0	29552.5
39	CENTRO DE ESTUDIOS CRISTOBAL COLON A. C.	AV. DIAZ MIRON # 2602 FRACC. MODERNO	2310	1386	396	198	3350.3	27324.0	14256.0	7078.5	32868.0	4477.8	1116.0	90470.5
40	CENTRO DE ESTUDIOS CRISTOBAL COLON	COLLADO # 571 ESQ. LAFRAGUA COL. ZARAGOZA	640	384	110	54.5	928.2	7570.3	3949.7	1930.5	9106.3	1221.2	558.0	25264.2
41	COLEGIO ANGLO MEXICANO DE LA	RIO PAPALOAPAN 1726 ESQ RIO MAGDALENA COL RIO	120	72	21	10	174.0	1419.4	740.6	357.5	1707.4	226.2	279.0	4904.1

	VERACRUZ													
42	COLEGIO CONTEMPORANEO DE VERACRUZ	FLORES MAGON NO. 153	304	182.4	52	26	440.9	3595.9	1876.1	929.5	4325.5	588.0	279.0	12034.9
43	CENTRO DE ESTUDIOS MALINALLI A.C.	PINZON NO. 351 FRACC. REFORMA	195	117	33	16.5	282.8	2306.6	1203.4	572.0	2774.6	361.8	279.0	7780.2
44	COLEGIO CHARLES DICKENS A.C.	AZALEAS 646	364	218.4	62	31	527.9	4305.6	2246.4	1072.5	5179.2	678.5	279.0	14289.1

Regarding DCs, Table D.2 shows the characteristics of the DCs used for the case of Veracruz

Table D.2. Features of the DCs considered for the case of Veracruz

ID	Name	Location	Capacity (m^3)	Area (m^2)	Cleaning cost (MXN)
A	Campo Militar No. 26-B	Av. Ejercito Mexicano S/N, 83/o batallon de infanteria	30	486	1174.76932
B	DICONSA facility	Lotes 13 and 14, Manzana XII, entre Avenida las Torres y prolongación Araucarias de la cd. Industrial	4000	4150	10031.5
C	World Trade Center	Boulevard Adolfo Ruiz Cortinez No. 3497, Col. Ylang Ylang	6500	11250	27193.7
D	Auditorio Benito Juarez	A. Salvador Díaz Mirón No. 1500, Col. Centro	44.6	1817.5	4393.3
E	Sistema de Agua y Saneamiento (SAS)	A. Cristobal Colón No. 425, Fraccionamiento Reforma	1142.4	952	2301.2
F	Cruz Roja Veracruz	A. Salvador Díaz Mirón No. 1698, Col. Centro	1428	1190	2876.5
G	DIF Municipal	Av. Matamoros S/N, Fraccionamiento Los Pinos	580.8	484	1169.9
H	Abarrotes DICONSA	Calle Totula Lote 1	92.4	77	186.1
I	SEDESOL Veracruz	CALLE: JOBO NUM EXT: 128 NUM INT: S/N COL: FRACC FLORESTA CP	108	90	217.5
J	SEDESOL Veracruz	VIA MUERTA NUM EXT: 24 NUM INT: S/N COL: LOMAS DEL MAR CP 94293	230.4	192	464.1

Acapulco

From the list of available facilities to serve as shelters published by SSPPC (2013) on the year of the flood in Acapulco, Table D.3 disaggregates the available refuges considered for the case study in the city. The capacity was obtained from SSPPC (2013), SSPPC (2014b) and (SSPPC, 2014a).

Table D.3. Available shelters in Acapulco in 2013

Name	Cap.	Real	Obt. Cap.	Final cap.	Lat	Long	Source	Relief capacity (m^3)	Cleaning cost	Mat cost	Blanket cost	Flashlight cost	Raincoat cost	Water container cost	Baby bathubs cost	Location cost
Esc. Prim. Gral. Emiliano Zapata	-	-	76	76	16.83	99.74	Shelter list	38	1071.63	13668.61	4674.01	1358.50	6308.00	859.37	279.00	28219.12
Jardín de niños Miguel Ángel	-	-	65	65	16.87	99.82	SEP	32.5	916.53	11690.26	3997.51	1144.00	5395.00	723.68	279.00	24145.97
Esc. Prim. Fed. Narciso Mendoza	150	-	0	150	16.92	99.84	SEP and Shelter list	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Kínder Club de Leones Internacional	-	-	42	42	16.74	99.76	SEP and Shelter list	21	592.22	7553.70	2583.00	715.00	3486.00	452.30	279.00	15661.23
Esc. Sec. Fed. Moisés Saenz	-	-	329	329	0.00	0.00	SEP	164.5	4639.05	59170.68	20233.53	5863.00	27307.00	3708.86	837.00	121759.12
Esc. Sec. Tec. 1 Juan de Dios Bátiz	432	-	0	432	16.87	99.89	SEP and Shelter list	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Esc. Sec. Gral. Ignacio Chávez	432	-	0	432	16.90	99.87	SEP	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Capilla San Felipe de Jesús	300	-	0	300	16.87	99.90	Google maps	150	4230.14	53955.02	18450.03	5362.50	24900.00	3392.25	837.00	111126.94
Esc. Sec. David Alfaro Siqueiros	150	300	0	150	0.00	0.00	SEP	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Colegio Simón Bolívar	-	-	284	284	16.88	99.90	Google maps	142	4004.53	51077.42	17466.03	5076.50	23572.00	3211.33	558.00	104965.81
CECyTEG No. 1	350	-	0	350	16.87	99.92	Google maps	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Esc. Prim. Héroes de Guerrero	350	-	0	350	16.85	99.81	SEP and Shelter list	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Jardín de Niños Pensador Mexicano	100	-	0	100	16.91	99.74	SEP	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Sec. No. 14 Miguel Alemán Valdez	100	-	0	100	16.87	99.99	SEP	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Sec. Fed. Acapulco No. 4	100	-	0	100	16.86	99.87	Google maps	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Capilla Espíritu Santo	80	-	0	80	16.87	99.91	Shelter list and Google MAPS	40	1128.04	14388.01	4920.01	1430.00	6640.00	904.60	279.00	29689.65

Esc. Prim. Rubén Mora Gutiérrez	100	-	0	100	16.87	99.91	SEP and Shelter list	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim. Independencia	-	-	195	195	16.86	99.89	SEP	97.5	2749.59	35070.77	11992.52	3432.00	16185.00	2171.04	279.00	71879.91
Jardín de niños Sor Juana Inés de la Cruz	-	-	108	108	16.88	99.84	SEP and Shelter list	54	1522.85	19423.81	6642.01	1930.50	8964.00	1221.21	279.00	39983.38
Capilla del Pilar	60	-	0	60	16.87	99.87	Shelter list and Google MAPS	30	846.03	10791.00	3690.01	1072.50	4980.00	678.45	279.00	22336.99
Seminario del Buen Pastor	200	-	0	200	16.86	99.85	Shelter list and Google MAPS	100	2820.09	35970.02	12300.02	3575.00	16600.00	2261.50	558.00	74084.62
Esc. Prim. María Orozco de Marrón	432	-	0	432	16.85	99.85	SEP and Shelter list	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Federación de Taxistas de Guerrero A.C	192	-	0	192	16.84	99.89	Shelter list	96	2707.29	34531.21	11808.02	3432.00	15936.00	2171.04	279.00	70864.56
Esc. Prim. Guadalupe Victoria	150	-	0	150	0.00	0.00	Google maps	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Centro de Bienestar Social IMSS	-	-	54	54	16.90	99.85	Shelter list	27	761.42	9711.90	3321.00	929.50	4482.00	587.99	279.00	20072.82
Esc. Prim. Club de Leones de Acapulco	-	300	0	300	16.87	99.82	Google maps	150	4230.14	53955.02	18450.03	5362.50	24900.00	3392.25	837.00	111126.94
Esc. Prim. Fed. Francisco Figueroa Mata	-	-	231	231	16.85	99.82	Shelter list	115.5	3257.21	41545.37	14206.52	4075.50	19173.00	2578.11	558.00	85393.70
Esc. Prim. Artículo 123	260	-	0	260	0.00	0.00	SEP	130	3666.12	46761.02	15990.02	4647.50	21580.00	2939.95	558.00	96142.61
Esc. Prim. Guadalupe Victoria	285	-	0	285	16.92	99.96	SEP and Shelter list	142.5	4018.63	51257.27	17527.53	5076.50	23655.00	3211.33	558.00	105304.26
Centro de Salud	20	-	0	20	16.88	99.95	Google maps	10	282.01	3597.00	1230.00	357.50	1660.00	226.15	279.00	7631.66
Esc. Prim. Lázaro Cárdenas del Río	-	-	120	120	16.86	99.82	SEP and Shelter list	60	1692.05	21582.01	7380.01	2145.00	9960.00	1356.90	279.00	44394.97
Esc. Prim. La Patria es Primero	-	-	75	75	0.00	0.00	SEP	37.5	1057.53	13488.76	4612.51	1287.00	6225.00	814.14	279.00	27763.94
Kínder Rafael Ortega	120	-	0	120	16.91	99.84	SEP and Shelter list	60	1692.05	21582.01	7380.01	2145.00	9960.00	1356.90	279.00	44394.97
Parroquia Perpetuo Socorro	150	-	0	150	16.90	99.84	Shelter list	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Jardín de niños Ovidio Decroly	-	-	100	100	0.00	0.00	SEP	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim. Emiliano Zapata	300	-	0	300	16.91	99.83	SEP	150	4230.14	53955.02	18450.03	5362.50	24900.00	3392.25	837.00	111126.94
Esc. Prim. Plan de Ayala (M) y Tierra y Libertad (V)	150	100	0	150	16.90	99.84	SEP	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Esc. Prim. Netzahualcóyotl	192	-	0	192	16.84	99.84	Shelter list	96	2707.29	34531.21	11808.02	3432.00	15936.00	2171.04	279.00	70864.56
Esc. Prim. Juan Escutia	160	-	0	160	16.91	99.84	SEP and Shelter list	80	2256.07	28776.01	9840.01	2860.00	13280.00	1809.20	279.00	59100.30
Esc. Sec. Fed. Amado Nervo	432	-	0	432	16.87	99.89	SEP and Shelter list	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Esc. Prim. Fernando Montes de Oca	86	-	0	86	16.81	99.82	SEP and Shelter list	43	1212.64	15467.11	5289.01	1501.50	7138.00	949.83	279.00	31837.08
Esc. Sec. Técnica 152	350	300	0	350	0.00	0.00	SEP	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Preparatoria No. 7	400	-	0	400	0.00	0.00	SEP	200	5640.18	71940.03	24600.04	7150.00	33200.00	4523.00	1116.00	148169.25

Esc. Sec. Tec. 117 Prof. Ramírez C.	-	-	302	302	16.90	99.85	SEP and Shelter list	151	4258.34	54314.72	18573.03	5362.50	25066.00	3392.25	837.00	111803.84
Parroquia de Nuestro Señor del Perdón	600	-	0	600	16.84	99.89	Google maps	300	8460.27	107910.05	36900.05	10725.00	49800.00	6784.50	1674.00	222253.87
Jardín de niños Jaime Torres Bodet	100	78	0	100	16.88	99.83	SEP and Shelter list	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim. Lázaro Cárdenas del Río	-	-	318	318	0.00	0.00	SEP	159	4483.94	57192.32	19557.03	5648.50	26394.00	3573.17	837.00	117685.97
Esc. Prim. Gregorio Torres Quintero	436	-	0	436	16.84	99.84	Google maps	218	6147.80	78414.63	26814.04	7793.50	36188.00	4930.07	1116.00	161404.04
Jardín de Niños José Antonio Adame	120	-	0	120	16.87	99.89	SEP	60	1692.05	21582.01	7380.01	2145.00	9960.00	1356.90	279.00	44394.97
Esc. Emperador Cuauhtémoc	144	-	0	144	16.88	99.95	SEP	72	2030.47	25898.41	8856.01	2574.00	11952.00	1628.28	279.00	53218.17
Esc. Sec. Fed. No. 3 Aztecalli	432	-	0	432	16.89	99.95	SEP and Shelter list	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Colegio de Bachilleres 2	500	-	0	500	16.87	99.89	SEP and Google maps	250	7050.23	89925.04	30750.05	8937.50	41500.00	5653.75	1395.00	185211.56
Parroquia de Nuestra Sra. de Fátima	258	-	0	258	16.88	99.95	Google maps and Shelter list	129	3637.92	46401.32	15867.02	4576.00	21414.00	2894.72	558.00	95348.98
Centro de Estudios Tec. Del Mar No. 18	1500	-	0	1500	16.88	99.94	SEP and Google maps	750	21150.68	269775.12	92250.14	26812.50	124500.00	16961.25	4185.00	555634.68
Templo Rosa de Sarón	75	-	0	75	16.92	99.77	Google maps	37.5	1057.53	13488.76	4612.51	1287.00	6225.00	814.14	279.00	27763.94
DIF Margarita Maza de Juárez	-	-	372	372	0.00	0.00	Google maps	186	5245.37	66904.23	22878.03	6649.50	30876.00	4206.39	837.00	137596.52
Esc. Prim. Melchor Ocampo	312	-	0	312	16.86	99.90	SEP	156	4399.34	56113.22	19188.03	5577.00	25896.00	3527.94	837.00	115538.53
Esc. Prim. Urbana Artículo 123	-	300	0	300	16.85	99.81	SEP and Shelter list	150	4230.14	53955.02	18450.03	5362.50	24900.00	3392.25	837.00	111126.94
Esc. Prim. Ignacio Zaragoza	400	400	0	400	16.79	99.79	Shelter list	200	5640.18	71940.03	24600.04	7150.00	33200.00	4523.00	1116.00	148169.25
Esc. Prim. Fed. Constituyentes de 1917	-	-	260	260	16.89	99.84	SEP and Shelter list	130	3666.12	46761.02	15990.02	4647.50	21580.00	2939.95	558.00	96142.61
Centro de Desarrollo Cultural No. 2 DIF “Leona Vicario”	-	-	174	174	16.88	99.83	SEP and Shelter list	87	2453.48	31293.91	10701.02	3074.50	14442.00	1944.89	279.00	64188.80
Esc. Prim. Fed. Ignacio López Rayón	-	-	150	150	16.88	99.84	SEP and Shelter list	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Jardín de niños Alicia Grovet Carrere	60	-	0	60	16.87	99.82	SEP and Shelter list	30	846.03	10791.00	3690.01	1072.50	4980.00	678.45	279.00	22336.99
Esc. Prim. Luis Donaldo Colosio	350	222	0	350	16.80	99.80	Shelter list	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Jardín de Niños Vasco de Quiroga	100	-	0	100	16.88	99.82	SEP and Shelter list	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim Eduardo Neri	-	-	78	78	16.89	99.95	SEP	39	1099.84	14028.31	4797.01	1358.50	6474.00	859.37	279.00	28896.02
CETIS No. 41	1000	-	0	1000	0.00	0.00	SEP	500	14100.45	179850.08	61500.09	17875.00	83000.00	11307.50	2790.00	370423.12
Esc. Prim. Congreso de Anáhuac	420	-	0	420	16.87	99.91	SEP and Shelter list	210	5922.19	75537.03	25830.04	7507.50	34860.00	4749.15	1116.00	155521.91
Esc. Secc. Jesús Mastache Román No. 2	400	-	0	400	16.87	99.91	SEP and Shelter list	200	5640.18	71940.03	24600.04	7150.00	33200.00	4523.00	1116.00	148169.25

Esc. Prim. Vicente Guerrero	360	-	0	360	16.87	99.90	SEP	180	5076.16	64746.03	22140.03	6435.00	29880.00	4070.70	837.00	133184.92
Esc. Prim. Mat. Emiliano Zapata	300	-	0	300	16.84	99.89	SEP	150	4230.14	53955.02	18450.03	5362.50	24900.00	3392.25	837.00	111126.94
Jardín de niños Educadora Guerrerense	144	-	0	144	16.88	99.90	Google maps and Shelter list	72	2030.47	25898.41	8856.01	2574.00	11952.00	1628.28	279.00	53218.17
Centro Cultural Deportivo ISSSTE	160	-	0	160	16.88	99.90	CONACULTA	80	2256.07	28776.01	9840.01	2860.00	13280.00	1809.20	279.00	59100.30
Jardín de niños Luz María Serradel	150	-	0	150	16.88	99.90	SEP and Shelter list	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Esc. Sec. Juan N. Álvarez	-	-	102	102	16.75	99.75	SEP and Shelter list	51	1438.25	18344.71	6273.01	1787.50	8466.00	1130.75	279.00	37719.21
Esc. Prim. Felícitas V. Jiménez	-	-	93	93	16.75	99.74	SEP and Shelter list	46.5	1311.34	16726.06	5719.51	1644.50	7719.00	1040.29	279.00	34439.70
Colegio de Bachilleres No. 16	280	-	0	280	16.91	99.83	SEP and Shelter list	140	3948.13	50358.02	17220.03	5005.00	23240.00	3166.10	558.00	103495.27
Templo El Buen Pastor	50	-	0	50	16.90	99.83	SEP and Shelter list	25	705.02	8992.50	3075.00	858.00	4150.00	542.76	279.00	18602.29
Colegio Leopoldo Díaz Escudero	350	-	0	350	16.86	99.90	SEP and Shelter list	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Esc. Prim. Federal Justo Sierra	250	-	0	250	16.86	99.90	SEP and Shelter list	125	3525.11	44962.52	15375.02	4433.00	20750.00	2804.26	558.00	92407.92
Unidad Deportiva Acapulco	500	-	0	500	16.86	99.90	SEP and Shelter list	250	7050.23	89925.04	30750.05	8937.50	41500.00	5653.75	1395.00	185211.56
Jardín de Niños Teresa Gaminde	-	-	60	60	0.00	0.00	SEP and Shelter list	30	846.03	10791.00	3690.01	1072.50	4980.00	678.45	279.00	22336.99
Esc. Prim. José Agustín Ramírez	1100	-	0	1100	16.87	99.89	SEP and Shelter list	550	15510.50	197835.09	67650.10	19662.50	91300.00	12438.25	3069.00	407465.44
Colegio Español	624	-	0	624	16.87	99.89	Google maps and Shelter list	312	8798.68	112226.45	38376.06	11154.00	51792.00	7055.88	1674.00	231077.07
Iglesia San José	350	-	0	350	16.80	99.83	Google maps and Shelter list	175	4935.16	62947.53	21525.03	6220.50	29050.00	3935.01	837.00	129450.23
Esc. Prim. Justicia Social	-	-	77	77	0.00	0.00	SEP and Google maps	38.5	1085.74	13848.46	4735.51	1358.50	6391.00	859.37	279.00	28557.57
Unidad Deportiva Jorge Campos	-	20	680	20	16.89	99.82	Google maps and Shelter list	10	282.01	3597.00	1230.00	357.50	1660.00	226.15	279.00	7631.66
Esc. Prim. Gabriela Mistral	-	-	240	240	16.89	99.83	SEP and Shelter list	120	3384.11	43164.02	14760.02	4290.00	19920.00	2713.80	558.00	88789.95
Iglesia Jesucristo de los Últimos Días	-	-	123	123	16.91	99.82	Shelter list	61.5	1734.36	22121.56	7564.51	2145.00	10209.00	1356.90	279.00	45410.33
Cetis No. 90	250	200	569	250	16.89	99.83	SEP and Shelter list	125	3525.11	44962.52	15375.02	4433.00	20750.00	2804.26	558.00	92407.92
Esc. Prim. Plan de Ayutla	180	-	0	180	0.00	99.41	SEP and Google maps	90	2538.08	32373.01	11070.02	3217.50	14940.00	2035.35	279.00	66452.96
Esc. Sec. Tec. No. 138	400	-	0	400	16.91	99.94	SEP and Shelter list	200	5640.18	71940.03	24600.04	7150.00	33200.00	4523.00	1116.00	148169.25
Santuario de Nuestro Padre Jesús	150	-	0	150	16.87	99.90	Google maps and Shelter list	75	2115.07	26977.51	9225.01	2645.50	12450.00	1673.51	279.00	55365.60
Esc. Prim. Juan Álvarez	-	-	255	255	0.00	0.00	SEP and Google maps	127.5	3595.62	45861.77	15682.52	4504.50	21165.00	2849.49	558.00	94216.90
Esc. Prim. Fed. Solidaridad	180	-	0	180	16.87	99.87	SEP and Google maps	90	2538.08	32373.01	11070.02	3217.50	14940.00	2035.35	279.00	66452.96

Esc. Prim. Simón Bolívar	-	-	301	301	16.90	99.85	SEP and Shelter list	150.5	4244.24	54134.87	18511.53	5362.50	24983.00	3392.25	837.00	111465.39
Esc. Prim. Leona Vicario	-	-	204	204	16.91	99.85	SEP and Shelter list	102	2876.49	36689.42	12546.02	3646.50	16932.00	2306.73	558.00	75555.16
Kínder Juan R. Escudero	100	-	0	100	16.91	99.84	SEP and Shelter list	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim. Guerrero es Primero	100	-	0	100	16.92	99.84	SEP and Shelter list	50	1410.05	17985.01	6150.01	1787.50	8300.00	1130.75	279.00	37042.31
Esc. Prim. Patria y Libertad	200	-	0	200	16.88	99.91	SEP and Shelter list	100	2820.09	35970.02	12300.02	3575.00	16600.00	2261.50	558.00	74084.62
Esc. Prim. Silvestre Castro	432	-	0	432	16.86	99.92	SEP and Shelter list	216	6091.40	77695.23	26568.04	7722.00	35856.00	4884.84	1116.00	159933.51
Kínder Acamapichtli	60	-	0	60	16.92	99.84	SEP	30	846.03	10791.00	3690.01	1072.50	4980.00	678.45	279.00	22336.99
Unidad Deportiva Vicente Suárez	90	-	0	90	0.00	0.00	Google maps	45	1269.04	16186.51	5535.01	1573.00	7470.00	995.06	279.00	33307.62

Similarly, Table D.4 displays the DCs identified in the city of Acapulco along with their characteristics.

Table D.4. DCs available for Acapulco city

ID	Name	Location	Area	Usable area	Total capacity	Cleanning cost
A	Casa de la Cultura		840	504	1008	2030.465
B	Coordinación Regional de Protección Civil en zona diamante	Boulevard de las Naciones Km 14, S/N, Col. Plan de los Amates. C.P. 39931. Acapulco	3420	2052	4104	8266.895
C	Expo Mundo Imperial.	Boulevard de Las Naciones, esquina Boulevard Barra Vieja, Colonia Plan de los Amates, Acapulco	3600	2160	4320	8701.995
D	Cuartel Regional de la Policía del Estado de San Isidro	Calle Emiliano Zapata S/N, Col. Roca de Oro, San Isidro, Acapulco Guerrero.	375	225	450	906.4578
E	Base Aérea de pie de la Cuesta and Octavo batallon de infanteria	Pie de la Cuesta Acapulco	4900	2940	5880	11844.38
F	Base de la Octava Región Naval	Privada de la Marina 1, Icacos, C.P 39860, Acapulco	990	594	1188	2393.049
G	Aeropuerto Internacional de Acapulco	Blvd. De las Naciones S/n, Plan de los Amates, 39931	36000	21600	43200	87019.95
H	Ventanilla SEDESOL Palacio Federal	Avenida Costera Miguel Aleman 315 (Palacio Federal)	3500	2100	4200	8460.273
I	Ventanilla SEDESOL Mangos	Avenida Mangos, Num 1, Esquina Calle Ciprés, Col. Jardín Mangos	132	79.2	158.4	319.0731
J	Oficinas PC	CALLE HORNITOS No. 7 39300 ACAPULCO DE JUÁREZ, GUERRERO	543	325.8	651.6	1312.551
K	Tienda DICONSA	CALLE FLORIDA 12 39700 ACAPULCO DE JUREZ, GUERRERO	184	110.4	220.8	444.7686
L	Miscelanea DICONSA	CALLE 33 42 39700 ACAPULCO DE JUREZ	126	75.6	151.2	304.5698
M	CD Liconsa Acapulco	Cristóbal Colón 17, 39671 Acapulco de Juárez, Guerrero, Mexico	720	432	1728	1740.399
N	Campo Militar	Calle 2	4434	2660.4	10641.6	10717.96

Villahermosa

Table D.5 contains the details of the 443 shelters used for the analysis in the case of Villahermosa, including the details used as input into the optimisation models.

Table D.5. Available shelters in Villahermosa in 2007

ID	NOMBRE_	DIRECCION	AREA	INDOORS AREA	PEOPLE CAPACITY	Cleaning cost	Mat cost	Blanket cost	Flashlight cost	Raincoat cost	Water container cost	Baby bathubs cost	Location cost	Storage capacity
1	Dios es Amor	Framboyan	454.475	181.79	31	439.4266	5575.352	1906.503	500.5	2573	316.61	45.23	11356.62	15.5
2	Adventista del 7º DÍa	Paseo Tropical	300.658	120.2632	20	290.7027	3597.002	1230.002	357.5	1660	226.15	45.23	7406.586	10
3	El Sr. es mi Luz	Recinto Lirios	5697.859	2279.144	390	5509.193	70141.53	23985.04	6935.5	32370	4387.31	180.92	143509.5	195
4	Manuel Fdo. Beltrán	Paseo Tropical	35796.47	14318.59	2454	34611.19	441352.1	150921.2	43829.5	203682	27725.99	1130.75	903252.7	1227
5	Colegio de Bachilleres	Paseo Tropical	6685.885	2674.354	458	6464.504	82371.34	28167.04	8151	38014	5156.22	226.15	168550.3	229
6	Sra. de Guadalupe	Paseo Tropical	13628.01	5451.204	934	13176.76	167980	57441.08	16659.5	77522	10538.59	452.3	343770.2	467
7	Monte Horeb	Emiliano Zapata	10018.95	4007.578	687	9687.201	123557	42250.56	12226.5	57021	7734.33	316.61	252793.2	343.5
8	Adventista del 7º DÍa	Plan de Iguala	3867.953	1547.181	265	3739.879	47660.27	16297.52	4719	21995	2985.18	135.69	97532.54	132.5
9	Profr. Sabino Ulin Lamoyl	Plan de Guadalupe	1341.636	536.6544	91	1297.212	16366.36	5596.508	1573	7553	995.06	45.23	33426.37	45.5
10	Kinder	Plan de Guadalupe	4790.328	1916.131	328	4631.712	58990.83	20172.03	5863	27224	3708.86	180.92	120771.3	164
11	Jesús el Divino Salvador	Gral. Ignacio Gutiérrez	31800.29	12720.12	2180	30747.33	392073.2	134070.2	38967.5	180940	24650.35	995.06	802443.6	1090
12	Principe de Paz	Francisco y Madero	24111.81	9644.725	1653	23313.43	297292.2	101659.7	29529.5	137199	18679.99	768.91	608442.7	826.5
13	Graciela Pintado de Madrazo	Gral. Carlos Green	13360.87	5344.348	916	12918.47	164742.7	56334.08	16373.5	76028	10357.67	452.3	337206.7	458
14	Esperanza Iris	Av. Corozal	745489.8	1945	333	4701.495	59890.08	20479.53	5934.5	27639	3754.09	180.92	122579.6	166.5
15	Iglesia Adventista del 7º DÍa	Prol. Plutarco Elias Calles	160029	128	21	309.4043	3776.852	1291.502	357.5	1743	226.15	45.23	7749.638	10.5
16	Luz y Verdad	Carlos Green	160029	120	20	290.0665	3597.002	1230.002	357.5	1660	226.15	45.23	7405.95	10
17	Marcelo Javier Arias	El Manzano	76159.41	238	40	575.2986	7194.003	2460.004	715	3320	452.3	45.23	14761.84	20
18	16 de Septiembre	El Manzano	410397.8	450	77	1087.749	13848.46	4735.507	1358.5	6391	859.37	45.23	28325.81	38.5
19	Evangelio Completo	Emiliano Zapata	4300.748	1720.299	294	4158.343	52875.92	18081.03	5219.5	24402	3301.79	135.69	108174.3	147
20	Templo Peniel	Gral. Emiliano Zapata	104588.4	288	49	696.1596	8812.654	3013.504	858	4067	542.76	45.23	18035.31	24.5

21	Thelma Beatriz Asencio Hidalgo	Av. Las Mercedes	26707.22	10682.89	1831	25822.9	329305.5	112606.7	32675.5	151973	20670.11	859.37	673913	915.5
22	Vicente Juevelo	Av. Las Mercedes	26707.22	10682.89	1831	25822.9	329305.5	112606.7	32675.5	151973	20670.11	859.37	673913	915.5
23	Cristo es la Respuesta	Fraternidad	410397.8	200	34	483.4442	6114.903	2091.003	572	2822	361.84	45.23	12490.42	17
24	Elsa Cordoba	Gabriela Mistral	940.577	376.2308	64	909.4329	11510.4	3936.006	1144	5312	723.68	45.23	23580.75	32
25	Rosario MarÍa Gutiérrez Eskilsen	Mario Gutiérrez Lipse	758.61	303.444	52	733.4912	9352.204	3198.005	929.5	4316	587.99	45.23	19162.42	26
26	Diana Laura Vidal de Colosio	Mario Gutiérrez Lipse	2290.462	916.1848	157	2214.621	28236.46	9655.514	2788.5	13031	1763.97	90.46	57780.53	78.5
27	San José	RÍo Pichucalco	14990.03	5996.01	1027	14493.68	184706	63160.59	18304	85241	11578.88	497.53	377981.7	513.5
28	Adventista del 7º. DÍa		2224.52	889.808	152	2150.862	27337.21	9348.014	2717	12616	1718.74	90.46	55978.29	76
29	Jaime Torres Badel	R/A Buenavista 1a. Sección	5825.383	2330.153	399	5632.495	71760.18	24538.54	7078.5	33117	4477.77	180.92	146785.4	199.5
30	24 de Febrero	Anacleto Canabal 2da. Sección	44071.66	484	82	1169.935	14747.71	5043.007	1430	6806	904.6	45.23	30146.48	41
31	Profra. Soledad C. Cruz	Anacleto Canabal 2da. Sección	146697.6	910	156	2199.671	28056.61	9594.014	2788.5	12948	1763.97	90.46	57441.23	78
32	Sam's Club	Av. Adolfo Ruiz Cortines	14664.36	5865.745	1005	14178.8	180749.3	61807.59	17946.5	83415	11352.73	497.53	369947.5	502.5
33	Cinépolis	Prol. Periférico Carlos Pellicer Cámara, esq. con Adolfo Ruiz Cortines	21080.1	8432.042	1445	20382.11	259883.4	88867.63	25811.5	119935	16328.03	678.45	531886.1	722.5
34	Suburbia	Av. Adolfo Ruiz Cortines	3969.988	1587.995	272	3838.535	48919.22	16728.02	4862	22576	3075.64	135.69	100135.1	136
35	Chedraui	Av. Adolfo Ruiz Cortines	30239.73	12095.89	2073	29238.44	372829.2	127489.7	37037	172059	23429.14	949.83	763032.3	1036.5
36	Superama	Prol. 27 de Febrero, esq. con Av. Paseo Tabasco	9588.156	3835.262	657	9270.676	118161.5	40405.56	11726	54531	7417.72	316.61	241829.1	328.5
37	Planetario	Av. Paseo Tabasco, esq. con Planetario	9106.033	3642.413	624	8804.517	112226.4	38376.06	11154	51792	7055.88	316.61	229725.5	312
38	Liverpool	Av. Paseo Tabasco, esq. con Retorno VÍa 3	9041.264	3616.506	619	8741.893	111327.2	38068.56	11011	51377	6965.42	316.61	227807.7	309.5
39	GalerÍa Tabasco 2000	Av. Paseo Tabasco	12381.13	4952.453	848	11971.17	152512.9	52152.08	15158	70384	9588.76	407.07	312173.9	424
40	Autotransportes Tuxtla Gutiérrez 1¬ y 2¬ Clase		10323.02	4129.208	707	9981.208	127154	43480.56	12584	58681	7960.48	361.84	260203.1	353.5
41	Central de Autobuses de 2¬ Clase		30466.38	12186.55	2089	29457.59	375706.8	128473.7	37323	173387	23610.06	949.83	768908	1044.5
42	San Juan Bautista	RÍo Mezcalapa	117349.3	416	71	1005.564	12769.36	4366.506	1215.5	5893	768.91	45.23	26064.07	35.5
43	Wal-Mart	Av. Universidad, esq. con Adolfo Ruiz Cortines	26062.26	10424.9	1787	25199.3	321392.1	109900.7	31889	148321	20172.58	814.14	657688.8	893.5
44	Luis Donaldo Colosio	Abedul	11011.4	4404.561	755	10646.8	135786.8	46432.57	13442	62665	8503.24	361.84	277838.3	377.5
45	Museo de La Venta		110846.2	44338.48	7600	107175.9	1366861	467400.7	135850	630800	85937	3437.48	2797462	3800
46	Museo Regional de AntropologÍa Carlos Pellicer	Zona CICOM	6427.516	2571.006	440	6214.69	79134.03	27060.04	7865	36520	4975.3	226.15	161995.2	220

47	Centro de Inv. de Las Culturas Olmeca y Maya		4387.523	1755.009	300	4242.245	53955.02	18450.03	5362.5	24900	3392.25	135.69	110437.7	150
48	Central de Autobuses de 1¬ Clase		4731.688	1892.675	324	4575.014	58271.43	19926.03	5791.5	26892	3663.63	180.92	119300.5	162
49	Teatro Esperanza Iris	Periférico Carlos Pellicer Cámara	8965.213	3586.085	614	8668.36	110427.9	37761.06	10939.5	50962	6920.19	316.61	225995.7	307
50	Casa de Artes "José Gorostiza"	Periférico Carlos Pellicer Cámara	9095.777	3638.311	623	8794.601	112046.6	38314.56	11082.5	51709	7010.65	316.61	229274.5	311.5
51	Casa de Artes El Jaguar Despertado		955.535	382.214	65	923.8956	11690.26	3997.506	1144	5395	723.68	45.23	23919.57	32.5
52	Casa de Los Azulejos		957.932	383.1728	65	926.2133	11690.26	3997.506	1144	5395	723.68	45.23	23921.88	32.5
53	Centro Cultural Villa Hermosa		1095.232	438.0928	75	1058.967	13488.76	4612.507	1287	6225	814.14	45.23	27531.6	37.5
54	Chedraui	Av. Fco. Javier Mina, esq. con Lamberto Castellanos	10236.65	4094.662	701	9897.701	126074.9	43111.56	12512.5	58183	7915.25	361.84	258056.8	350.5
55	Soriana	Periférico Carlos Pellicer Cámara, esq. con Usumacinta	56116.76	22446.7	3848	54258.64	692063.1	236652.3	68783	319384	43511.26	1763.97	1416416	1924
56	Cardesa	Eusebio Castillo, esq. con Bástar Sozaya	10359.24	4143.696	710	10016.23	127693.6	43665.06	12655.5	58930	8005.71	361.84	261327.9	355
57	La Sultana	Av. Adolfo Ruiz Cortines, casi esq. con Gil y Sáenz	3550.313	1420.125	243	3432.756	43703.57	14944.52	4290	20169	2713.8	135.69	89389.34	121.5
58	Casa de La Trova Tabasqueña	Zona CICOM	860.082	344.0328	58	831.6033	10431.3	3567.005	1001	4814	633.22	45.23	21323.36	29
59	Teatro IMSS	Av. Gral. Augusto César Sandino	2423.336	969.3344	166	2343.095	29855.11	10209.02	2931.5	13778	1854.43	90.46	61061.61	83
60	Aurrerá	Periférico Carlos Pellicer Cámara, esq. con Usumacinta	872.129	348.8516	59	843.2514	10611.15	3628.505	1001	4897	633.22	45.23	21659.36	29.5
61	Sam's Club	Periférico Carlos Pellicer Cámara, esq. con Usumacinta	33029.75	13211.9	2264	31936.08	407180.6	139236.2	40469	187912	25600.18	1040.29	833374.3	1132
62	Alvarado Playas del Rosario	Av. Esperanza Iris	1467.797	587.1188	100	1419.196	17985.01	6150.009	1787.5	8300	1130.75	45.23	36817.69	50
63	Fábricas de Francia	Av. H. Colegio Militar	3971.436	1588.574	272	3839.935	48919.22	16728.02	4862	22576	3075.64	135.69	100136.5	136
64	Chedraui	Av. QuintÍn Arauz	20195.93	8078.371	1384	19527.21	248912.5	85116.13	24739	114872	15649.58	633.22	509449.6	692
65	Wal-Mart	Av. QuintÍn Arauz	28507.77	11403.11	1954	27563.83	351427.1	120171.2	34892	162182	22072.24	904.6	719212.9	977
66	Famsa	Av. Prol. Paseo Usumacinta, esq. con Av. Las Américas	8720.305	3488.122	597	8431.561	107370.5	36715.55	10653.5	49551	6739.27	271.38	219732.8	298.5
67	Aurrerá	Av. Universidad, esq. con Periférico Carlos Pellicer Cámara	16987.37	6794.949	1164	16424.89	209345.5	71586.11	20806.5	96612	13161.93	542.76	428479.7	582
68	Comalli	Manuel Gil y Sáenz	3461.305	1384.522	237	3346.695	42624.47	14575.52	4218.5	19671	2668.57	135.69	87240.45	118.5
69	Chedraui	Dr. Lamberto Castellanos	3045.594	1218.238	208	2944.749	37408.82	12792.02	3718	17264	2351.96	135.69	76615.23	104
70	Comalcalco	Dr. Lamberto Castellanos	1399.203	559.6812	95	1352.873	17085.76	5842.509	1644.5	7885	1040.29	45.23	34896.16	47.5
71	Soriana	Periférico Carlos Pellicer Cámara	42994.41	17197.76	2948	41570.79	530198	181302.3	52695.5	244684	33334.51	1356.9	1085142	1474
72	Office Depot	Juan Estrada Torres	4137.734	1655.094	283	4000.727	50897.57	17404.53	5005	23489	3166.1	135.69	104098.6	141.5
73	Home Depot	Juan Estrada Torres, esq. con QuintÍn Arauz	10562.22	4224.886	724	10212.48	130211.5	44526.07	12941.5	60092	8186.63	361.84	266532	362

74	Wal-Mart	Av. Adolfo Ruiz Cortines	12909.34	5163.734	885	12481.89	159167.3	54427.58	15801.5	73455	9995.83	407.07	325736.2	442.5
75	Interactivo Papagayo		6239.176	2495.67	427	6032.586	76795.98	26260.54	7579	35441	4794.38	226.15	157129.6	213.5
76	La Venta		3475.547	1390.219	238	3360.466	42804.32	14637.02	4218.5	19754	2668.57	135.69	87578.57	119
77	S/D		3923.711	1569.484	269	3793.79	48379.67	16543.52	4790.5	22327	3030.41	135.69	99000.59	134.5
78	Plaza Sur	Venustiano Carranza, esq. con Pedro Fuentes	1540.216	616.0864	105	1489.217	18884.26	6457.51	1859	8715	1175.98	90.46	38671.42	52.5
79	Cunduacán	Eusebio Castillo, esq. con Hnos. Bástar Zozaya	472.09	188.836	32	456.4583	5755.202	1968.003	572	2656	361.84	45.23	11814.73	16
80	S/D	Hermanos Bástar Zozaya, entre Eusebui Castillo y JoaquÍn Camelio	487.882	195.1528	33	471.7274	5935.053	2029.503	572	2739	361.84	45.23	12154.35	16.5
81	Tecnológico	Carr. Villa Hermosa-Teapa	175938.5	9300	1594	22480.15	286681	98031.14	28457	132302	18001.54	723.68	586676.5	797
82	Iglesia NAL. Prebisteriana "Solo Cristo Salva"	Carr. a Estanzuela	502.478	200.9912	34	485.8401	6114.903	2091.003	572	2822	361.84	45.23	12492.82	17
83	Nuestra Señora del Carmen	Carr. a Estanzuela	1843.576	737.4304	126	1782.532	22661.11	7749.011	2216.5	10458	1402.13	90.46	46359.74	63
84	Efrain Rámirez Galmiche	Carr. a Estanzuela	574.537	229.8148	39	555.5131	7014.153	2398.504	643.5	3237	407.07	45.23	14300.97	19.5
85	Eusebio Castillo	Reforma-RÍo Viejo	236324	204	34	493.113	6114.903	2091.003	572	2822	361.84	45.23	12500.09	17
86	Señor de la Micericordia	Macuillis	5293.209	2117.284	362	5117.942	65105.73	22263.03	6435	30046	4070.7	180.92	133219.3	181
87	Ignacio Manuel Altamirano	Manuel Carrera	115125.6	360	61	870.1995	10970.85	3751.506	1072.5	5063	678.45	45.23	22451.74	30.5
88	Adventista del 7º. DÍa	And. El Cobo	3929.17	1571.668	269	3799.069	48379.67	16543.52	4790.5	22327	3030.41	135.69	99005.86	134.5
89	Jardin de Niños "Sor Juana de Tabasco"	Calle Principal	115125.6	690	118	1667.882	21222.31	7257.011	2073.5	9794	1311.67	90.46	43416.83	59
90	Francisco González Bocanegra	Marcelino Villamil	48573.88	270	46	652.6496	8273.104	2829.004	786.5	3818	497.53	45.23	16902.02	23
91	Esmirna	La unión	11996.74	4798.694	822	11599.5	147836.8	50553.07	14657.5	68226	9272.15	407.07	302552.1	411
92	La Candelaria	La Unión	25393.45	10157.38	1741	24552.63	313119	107071.7	31102.5	144503	19675.05	814.14	640838	870.5
93	Dios en México	Juan Pablo XXIII	593941.4	1200	205	2900.665	36869.27	12607.52	3646.5	17015	2306.73	135.69	75481.37	102.5
94	José Goroztiza	Av. Frutales	21814.91	8725.962	1495	21092.58	268875.9	91942.64	26669.5	124085	16870.79	678.45	550214.8	747.5
95	Juan Pablo II	Euleterio Vidamil	325171.4	788	135	1904.77	24279.76	8302.512	2359.5	11205	1492.59	90.46	49634.59	67.5
96	Carlos Pav. González	Juan Pablo XXIII	17427.33	6970.933	1195	16850.28	214920.8	73492.61	21307	99185	13478.54	542.76	439777	597.5
97	Cristo Rey	And. guaya	167973.5	360	61	870.1995	10970.85	3751.506	1072.5	5063	678.45	45.23	22451.74	30.5
98	Shadi	Calle Principal	119406.7	475	81	1148.18	14567.86	4981.507	1430	6723	904.6	45.23	29800.37	40.5
99	Macedinio Rivera	Calle Principal	48573.88	1217	208	2941.758	37408.82	12792.02	3718	17264	2351.96	135.69	76612.24	104
100	Nuestra Señora de Las	Gardenias y Tulipanes	1739.322	695.7288	119	1681.73	21402.16	7318.511	2073.5	9877	1311.67	90.46	43755.03	59.5

	Mercedes												
101	C.E.T.I.S. 70	Blvd. Industrial Nacional Mexicana	12837.21	5134.884	880	12412.15	158268.1	54120.08	15730	73040	9950.6	407.07	323928	440
102	C.E.C.A.T.I. 95	Blvd. Industrial Nacional Mexicana	11372.53	4549.012	779	10995.97	140103.2	47908.57	13871	64657	8774.62	361.84	286672.2	389.5
103	Josefina de Los Santos G.	Xochicalco	691.056	276.4224	47	668.174	8452.954	2890.504	786.5	3901	497.53	45.23	17241.89	23.5
104	Jes·s López Alamilla	Xochicalco	571.751	228.7004	39	552.8194	7014.153	2398.504	643.5	3237	407.07	45.23	14298.28	19.5
105	Gisell	Blvd. Adolfo Ruiz Cortines	356.483	142.5932	24	344.6793	4316.402	1476.002	429	1992	271.38	45.23	8874.693	12
106	Gisell	Blvd. Adolfo Ruiz Cortines	339.757	135.9028	23	328.5071	4136.552	1414.502	357.5	1909	226.15	45.23	8417.441	11.5
107	Primaria. Fed. Vesp. Lic Fco. Trujillo GurrÍa	Mariano Arista	850.421	340.1684	58	822.2621	10431.3	3567.005	1001	4814	633.22	45.23	21314.02	29
108	Rosario Ma. Gutiérrez Eskildsen	Ignacio RamÍrez	5469.334	2187.734	375	5288.235	67443.78	23062.53	6649.5	31125	4206.39	180.92	137956.4	187.5
109	CETCI	Juan ┴lvarez, esq. con Hnos. Bástar Sozaya	419.564	167.8256	28	405.6715	5035.802	1722.003	500.5	2324	316.61	45.23	10349.82	14
110	Colegio Latino Americano	Benito Juárez	1977.381	790.9524	135	1911.907	24279.76	8302.512	2359.5	11205	1492.59	90.46	49641.73	67.5
111	Primaria Urb. Estatal Fco. J. SantamarÍa	Mariano Arista	1062.038	424.8152	72	1026.872	12949.21	4428.007	1287	5976	814.14	45.23	26526.45	36
112	Lizardi	Calle Ejido	726.236	290.4944	49	702.1891	8812.654	3013.504	858	4067	542.76	45.23	18041.34	24.5
113	Ceferino Vázquez I. y Manuel GarcÍa	Revolución	2157.771	863.1084	147	2086.324	26437.96	9040.513	2574	12201	1628.28	90.46	54058.54	73.5
114	Manuel DÍaz Prieto y Dolores Ocaña	Miguel Hidalgo	1884.801	753.9204	129	1822.392	23200.66	7933.512	2288	10707	1447.36	90.46	47489.38	64.5
115	Luz del Mundo	Revolución, esq. con Juan Aldama	1118.809	447.5236	76	1081.763	13668.61	4674.007	1358.5	6308	859.37	45.23	27995.48	38
116	Señor de Tamulté y Gran Poder	Revolución, esq. con Méndez	1781.266	712.5064	122	1722.285	21941.71	7503.011	2145	10126	1356.9	90.46	44885.37	61
117	SinaÍ	Libertad	603.986	241.5944	41	583.987	7373.853	2521.504	715	3403	452.3	45.23	15094.87	20.5
118	Testigos de Jehová	Ignacio Comonfort	486.672	194.6688	33	470.5575	5935.053	2029.503	572	2739	361.84	45.23	12153.18	16.5
119	Luz del Mundo	Libertad, esq. con Abraham Bandala	781.432	312.5728	53	755.5575	9532.054	3259.505	929.5	4399	587.99	45.23	19508.84	26.5
120	P.I.A.S.E.T.	Revolución	1673.523	669.4092	114	1618.11	20502.91	7011.01	2002	9462	1266.44	90.46	41952.93	57
121	Liceo Anglo-mexicano	Cristóbal Colón	886.842	354.7368	60	857.4772	10791	3690.005	1072.5	4980	678.45	45.23	22114.67	30
122	Jes·s Buen Pastor	Juan Aldama	621.707	248.6828	42	601.1212	7553.703	2583.004	715	3486	452.3	45.23	15436.36	21
123	M. Montessori	Calle Tiro	475.262	190.1048	32	459.5253	5755.202	1968.003	572	2656	361.84	45.23	11817.8	16
124	Edu. Pedagógica	Calle Tenis	405.039	162.0156	27	391.6275	4855.952	1660.502	429	2241	271.38	45.23	9894.692	13.5
125	Lic. Manuel Sánchez Mármol	Av. Mártires de Cananea	4743.18	1897.272	325	4586.125	58451.28	19987.53	5791.5	26975	3663.63	180.92	119636	162.5
126	Veterinaria Zootecnista	Av. Mártires de RÍo Blanco	1994.391	797.7564	136	1928.353	24459.61	8364.012	2431	11288	1537.82	90.46	50099.26	68

127	Arturo Rosenbluer	1¬ Cda. Paseo La Sierra, casi esq. con Paseo de La Sierra	1575.264	630.1056	108	1523.104	19423.81	6642.01	1930.5	8964	1221.21	90.46	39795.09	54
128	Las Gardenias	Periférico Carlos Pellicer Cámara, esq. con Paseo de La Sierra	1497.877	599.1508	102	1448.28	18344.71	6273.009	1787.5	8466	1130.75	90.46	37540.71	51
129	Colegio de PolicÍa y Tránsito	Av. 16 de Septiembre, casi esq. con Periférico Carlos Pellicer Cámara	12126.92	4850.768	831	11725.38	149455.4	51106.58	14800.5	68973	9362.61	407.07	305830.5	415.5
130	CONALEP	Periférico Carlos Pellicer Cámara, entre Manuel Reyes Castillo y Cda. Plutarco ElÍas Calles	14669.35	5867.738	1005	14183.62	180749.3	61807.59	17946.5	83415	11352.73	497.53	369952.3	502.5
131	Castañeda	Paseo de La Sierra, entre Priv. del Caminero y 1¬ Cda. Paseo de La Sierra	5370.227	2148.091	368	5192.41	66184.83	22632.03	6578	30544	4161.16	180.92	135473.4	184
132	Paido S·per Pensar	Av. César Sandino, casi esq. con Periférico Carlos Pellicer Cámara	4849.861	1939.944	332	4689.274	59710.23	20418.03	5934.5	27556	3754.09	180.92	122243	166
133	La Voz de La Piedra	Cda. Coronel Gregrorio Méndez Magaña, casi esq. con Periférico Carlos Pellicer Cámara	3304.211	1321.684	226	3194.803	40646.12	13899.02	4004	18758	2532.88	135.69	83170.51	113
134	Luis Donaldo Colosio Murrieta	Av. Principal Villa Las Fuentes	3723.02	1489.208	255	3599.745	45861.77	15682.52	4504.5	21165	2849.49	135.69	93798.72	127.5
135	Colegio Villahermosa	Belisario DomÍnguez, casi esq. con Periférico Carlos Pellicer Cámara	11101.86	4440.744	761	10734.26	136865.9	46801.57	13585	63163	8593.7	361.84	280105.3	380.5
136	Pedro Pulido "Supervisión"	Pedro Pulido	653.643	261.4572	44	631.9998	7913.403	2706.004	786.5	3652	497.53	45.23	16232.67	22
137	Ma. Montesino	Adán Correa	421.859	168.7436	28	407.8905	5035.802	1722.003	500.5	2324	316.61	45.23	10352.04	14
138	GuarderÍa Participativa	Av. Principal Villa Las Fuentes	4479.32	1791.728	307	4331.002	55213.97	18880.53	5434	25481	3437.48	180.92	112958.9	153.5
139	De Dios en México	Trinidad Malpica	789.859	315.9436	54	763.7055	9711.904	3321.005	929.5	4482	587.99	45.23	19841.33	27
140	Jesucristo Fuente de Vida	Urbano Castañeda	782.66	313.064	53	756.7448	9532.054	3259.505	929.5	4399	587.99	45.23	19510.02	26.5
141	Monte Horeb	Urbano Castañeda	392.912	157.1648	26	379.902	4676.102	1599.002	429	2158	271.38	45.23	9558.616	13
142	Videl Valle de México	Amate	7662.699	3065.08	525	7408.974	94421.29	32287.55	9366.5	43575	5925.13	271.38	193255.8	262.5
143	Rosa MÍstica	Jaime Reynés Escala	1203.699	481.4796	82	1163.843	14747.71	5043.007	1430	6806	904.6	45.23	30140.39	41
144	Colegio Tabasco	20 de Noviembre	35206.93	14082.77	2414	34041.17	434158.1	148461.2	43114.5	200362	27273.69	1130.75	888541.4	1207
145	Retoño de Isal	Josefa Ortiz de DomÍnguez	372.438	148.9752	25	360.106	4496.252	1537.502	429	2075	271.38	45.23	9214.47	12.5
146	Libertad	Plutarco ElÍas Calles	4450.691	1780.276	305	4303.321	54854.27	18757.53	5434	25315	3437.48	180.92	112282.5	152.5
147	Libertad	Plutarco ElÍas Calles	8640.189	3456.076	592	8354.098	106471.2	36408.05	10582	49136	6694.04	271.38	217916.8	296
148	Mami Laura	Fracc. Esmeralda	1122.132	448.8528	76	1084.976	13668.61	4674.007	1358.5	6308	859.37	45.23	27998.69	38
149	Mercedes Camacho	Av. Coronel Gregorio Méndez Magaña	707.646	283.0584	48	684.2147	8632.804	2952.004	858	3984	542.76	45.23	17699.01	24
150	El Calvario	a Ixtacomitán 1¬ Sección	351.617	140.6468	24	339.9744	4316.402	1476.002	429	1992	271.38	45.23	8869.988	12
151	Divino Niño	a Ixtacomitán 1¬ Sección	839.59	335.836	57	811.7898	10251.45	3505.505	1001	4731	633.22	45.23	20979.2	28.5

152	Señora de Tila	a Ixtacomitán 1¬ Sección	1592.879	637.1516	109	1540.136	19603.66	6703.51	1930.5	9047	1221.21	90.46	40136.47	54.5
153	Dádiva de Dios	Cda. Bugambilias	463.828	185.5312	31	448.4699	5575.352	1906.503	500.5	2573	316.61	45.23	11365.67	15.5
154	Tezihuatlán	RancherÍa Lagartera, 1¬ Sección	746.553	298.6212	51	721.8334	9172.354	3136.505	858	4233	542.76	45.23	18709.68	25.5
155	BrÍgida Alfaro	RancherÍa Lagartera, 1¬ Sección	1176.178	470.4712	80	1137.233	14388.01	4920.007	1430	6640	904.6	45.23	29465.08	40
156	El Porvenir	Ejido Tierra Amarilla, 1¬ Sección	24793.73	9917.491	1700	23972.77	305745.1	104550.2	30387.5	141100	19222.75	768.91	625747.2	850
157	Niñas y Niños	Ejido Tierra Amarilla, 1¬ Sección	34878.26	13951.3	2391	33723.38	430021.5	147046.7	42685.5	198453	27002.31	1085.52	880018	1195.5
158	La Virgen del Carmen	RancherÍa Lagartera, 1¬ Sección	6773.246	2709.298	464	6548.973	83450.44	28536.04	8294	38512	5246.68	226.15	170814.3	232
159	Adventista del 7º DÍa	Ejido Tierra Amarilla, 1¬ Sección	24793.73	9917.491	1700	23972.77	305745.1	104550.2	30387.5	141100	19222.75	768.91	625747.2	850
160	Carlos Pellicer Cámara	Samarkanda Nac.	2273.371	909.3484	155	2198.096	27876.76	9532.514	2717	12865	1718.74	90.46	56998.57	77.5
161	Samarkanda	Ejido Samarkanda, Nacajuca, Tab.	3106.783	1242.713	213	3003.912	38308.07	13099.52	3789.5	17679	2397.19	135.69	78412.88	106.5
162	J. Jes·s	Monte Albán	2647.277	1058.911	181	2559.621	32552.86	11131.52	3217.5	15023	2035.35	90.46	66610.31	90.5
163	Fausto Méndez Jiménez	C. S/N, entre Andador Guaya y CapulÍn	1452.507	581.0028	99	1404.412	17805.16	6088.509	1716	8217	1085.52	45.23	36361.83	49.5
164	Juan Salvador Trujillo	Doña Fidencia No 608	1869.657	747.8628	128	1807.75	23020.81	7872.012	2288	10624	1447.36	90.46	47150.39	64
165	MarÍa Inocencia Galván	Doña Fidencia, entre Pedro Fuentes y Bástar Zozaya	2891.984	1156.794	198	2796.226	35610.32	12177.02	3503.5	16434	2216.27	90.46	72827.79	99
166	Betel	Rosario M. Gutiérrez, entre ┴lvarez y JoaquÍn Camelio	483.711	193.4844	33	467.6945	5935.053	2029.503	572	2739	361.84	45.23	12150.32	16.5
167	Instituto Tabasco	Lino Merino No 711	5333.597	2133.439	365	5156.993	65645.28	22447.53	6506.5	30295	4115.93	180.92	134348.2	182.5
168	Tomás DÍaz Barleth	Eusebio Castillo No 1107	3528.868	1411.547	241	3412.021	43343.87	14821.52	4290	20003	2713.8	135.69	88719.9	120.5
169	Bolivia M. de Rivas	Hermenegildo Galeana	2270.075	908.03	155	2194.909	27876.76	9532.514	2717	12865	1718.74	90.46	56995.39	77.5
170	Escuela de Seguridad	Melchor Ocampo	683.614	273.4456	46	660.9784	8273.104	2829.004	786.5	3818	497.53	45.23	16910.35	23
171	Niños Héroes	Av. José Carmen Pérez A., esq. con Calle Ocho	4679.257	1871.703	320	4524.319	57552.02	19680.03	5720	26560	3618.4	180.92	117835.7	160
172	Adventista del 7o. DÍa	Calle 4	3459.547	1383.819	237	3344.996	42624.47	14575.52	4218.5	19671	2668.57	135.69	87238.75	118.5
173	Quetzalcóatl	Teólogos	340.244	136.0976	23	328.978	4136.552	1414.502	357.5	1909	226.15	45.23	8417.912	11.5
174	Gregorio Méndez	Teólogos	396.627	158.6508	27	383.494	4855.952	1660.502	429	2241	271.38	45.23	9886.559	13.5
175	José MartÍ	Constructores	1046.104	418.4416	71	1011.466	12769.36	4366.506	1215.5	5893	768.91	45.23	26069.97	35.5
176	Concepción Sánchez	Constructores	4047.818	1619.127	277	3913.788	49818.47	17035.53	4933.5	22991	3120.87	135.69	101948.8	138.5
177	COBATAB	Alfonso Vicent SaldÍvar	15122.08	6048.83	1036	14621.36	186324.7	63714.09	18518.5	85988	11714.57	497.53	381378.7	518
178	Maratana Cristo Viene	José Luis Peña	491.93	196.772	33	475.6414	5935.053	2029.503	572	2739	361.84	45.23	12158.27	16.5

179	Aquiles Serdán	Malecón Leandro Rovirosa Wade	503.869	201.5476	34	487.1851	6114.903	2091.003	572	2822	361.84	45.23	12494.16	17
180	Divino Redendor	Pedro Gutiérrez, esq. con Limbano BlandÍn	465.545	186.218	31	450.13	5575.352	1906.503	500.5	2573	316.61	45.23	11367.33	15.5
181	José Ma. Pino Suárez	Teólogos	711.904	284.7616	48	688.3317	8632.804	2952.004	858	3984	542.76	45.23	17703.13	24
182	Tecnológico 39	Médicos	19648.29	7859.314	1347	18997.7	242258.1	82840.62	24024	111801	15197.28	633.22	495751.9	673.5
183	J. N. Cuahutémoc	Circuito Municipal	4200.32	1680.128	288	4061.24	51796.82	17712.03	5148	23904	3256.56	135.69	106014.3	144
184	Corazoncito	Colombia, esq. con ┴frica	909.063	363.6252	62	878.9624	11150.7	3813.006	1072.5	5146	678.45	45.23	22784.85	31
185	J. Luis S. Zurita	Médicos	6649.494	2659.798	455	6429.318	81831.79	27982.54	8079.5	37765	5110.99	226.15	167425.3	227.5
186	Isaías de Dios Veites	Malecón Leandro Rovirosa Wade	1154.996	461.9984	79	1116.752	14208.16	4858.507	1358.5	6557	859.37	45.23	29003.52	39.5
187	Est. Chavitas	Pepe del Rivero	778.148	311.2592	53	752.3822	9532.054	3259.505	929.5	4399	587.99	45.23	19505.66	26.5
188	Nueva Vida	Calle 1	361.803	144.7212	24	349.8231	4316.402	1476.002	429	1992	271.38	45.23	8879.837	12
189	San Pablo	Av. Luis Donaldo Colosio	364.16	145.664	24	352.1021	4316.402	1476.002	429	1992	271.38	45.23	8882.116	12
190	Aidé Wade Rovirosa	Melchor Ocampo, casi esq. con C. Carlos Green	3375.74	1350.296	231	3263.964	41545.37	14206.52	4075.5	19173	2578.11	135.69	84978.15	115.5
191	Alfonso Caparoso Santa María	Carlos Green	6170.273	2468.109	423	5965.965	76076.58	26014.54	7507.5	35109	4749.15	226.15	155648.9	211.5
192	San José Obrero	Melchor Ocampo, esq. con Av. Alfonso Vera	6142.496	2456.998	421	5939.108	75716.88	25891.54	7507.5	34943	4749.15	226.15	154973.3	210.5
193	José Ma. Pino Suárez	Periférico Carlos Pellicer Cámara	6262.43	2504.972	429	6055.071	77155.68	26383.54	7650.5	35607	4839.61	226.15	157917.6	214.5
194	División Académica de Ciencias Sociales de La UJAT	Centenario	6347.594	2539.038	435	6137.415	78234.78	26752.54	7722	36105	4884.84	226.15	160062.7	217.5
195	Centro de Estudios Culturales	Av. Esperanza Iris 135	4785.18	1914.072	328	4626.735	58990.83	20172.03	5863	27224	3708.86	180.92	120766.4	164
196	CBTIS 32	Av. Esperanza Iris	29113.24	11645.3	1996	28149.25	358980.8	122754.2	35678.5	165668	22569.77	904.6	734705.1	998
197	Adolfo López Mateos	Dalia	4518.529	1807.412	309	4368.913	55573.67	19003.53	5505.5	25647	3482.71	180.92	113762.2	154.5
198	Manuela Josefa Padrón	José Gorostiza	4416.518	1766.607	302	4270.28	54314.72	18573.03	5362.5	25066	3392.25	180.92	111159.7	151
199	Josefina Vicens	Paseo de La Sierra	878.104	351.2416	60	849.0285	10791	3690.005	1072.5	4980	678.45	45.23	22106.22	30
200	Soldado de La Cruz	Paseo Usumacinta 119	372.703	149.0812	25	360.3622	4496.252	1537.502	429	2075	271.38	45.23	9214.726	12.5
201	Colegio Montessori	Cda. Esperanza Iris	3511.814	1404.726	240	3395.532	43164.02	14760.02	4290	19920	2713.8	135.69	88379.06	120
202	Colegio México	Paseo de La Sierra	5972.441	2388.976	409	5774.684	73558.68	25153.54	7293	33947	4613.46	226.15	150566.5	204.5
203	Oficios del Centro	Av. Esperanza Iris	2444.574	977.8296	167	2363.63	30034.96	10270.52	2931.5	13861	1854.43	90.46	61406.5	83.5
204	San Juan de Los Lagos	Benito Juárez	311.461	124.5844	21	301.148	3776.852	1291.502	357.5	1743	226.15	45.23	7741.382	10.5
205	Librería SEP	Zona CICOM	685.615	274.246	47	662.9131	8452.954	2890.504	786.5	3901	497.53	45.23	17236.63	23.5

206	Escritores "José Gorotiza"	Zona CICOM	935.33	374.132	64	904.3597	11510.4	3936.006	1144	5312	723.68	45.23	23575.68	32
207	Esc. Ceiba, Centro de Estudios de Bellas Artes	Zona CICOM	10851.99	4340.794	744	10492.66	133808.5	45756.07	13299	61752	8412.78	361.84	273882.8	372
208	Estancia Infantil Chikis	J. Ma. Graham Pons	710.139	284.0556	48	686.6251	8632.804	2952.004	858	3984	542.76	45.23	17701.42	24
209	Adventista del 7º DÍa	1º de Mayo 230	349.906	139.9624	23	338.32	4136.552	1414.502	357.5	1909	226.15	45.23	8427.254	11.5
210	Gregorio Méndez Magaña	Av. 27 de Febrero, casi esq. con Paseo Usumacinta	3173.371	1269.348	217	3068.295	39027.47	13345.52	3861	18011	2442.42	135.69	79891.39	108.5
211	Centro Cultural Rosa Cruz	El ┴guila	1078.703	431.4812	73	1042.985	13129.06	4489.507	1287	6059	814.14	45.23	26866.92	36.5
212	COBACH Plantel No. 1	Velódromo Cd. Deportiva	13605.76	5442.305	932	13155.25	167620.3	57318.08	16659.5	77356	10538.59	452.3	343100	466
213	Testigos de Jehová	Velódromo Cd. Deportiva	9872.836	3949.134	676	9545.93	121578.7	41574.06	12083.5	56108	7643.87	316.61	248850.6	338
214	San Sebastián	Av. Coronel Gregorio Méndez Magaña	1498.852	599.5408	102	1449.223	18344.71	6273.009	1787.5	8466	1130.75	90.46	37541.65	51
215	Killymanjaro	Velódromo Cd. Deportiva	2454.5	981.8	168	2373.227	30214.81	10332.02	3003	13944	1899.66	90.46	61857.18	84
216	André I. Duarte Foucher	Melchor Ocampo y Aquiles Serdán	2509.861	1003.944	172	2426.755	30934.21	10578.02	3074.5	14276	1944.89	90.46	63324.83	86
217	FantasÍa	Altamira	968.715	387.486	66	936.6392	11870.11	4059.006	1144	5478	723.68	45.23	24256.66	33
218	Scout de Tabasco	El ┴guila 232	9025.111	3610.044	618	8726.275	111147.3	38007.06	11011	51294	6965.42	316.61	227467.7	309
219	Centro de Bachillerato Tec. Grijalva	Altamira, esq. con Nicolás Bravo	1813.424	725.3696	124	1753.379	22301.41	7626.011	2216.5	10292	1402.13	90.46	45681.89	62
220	27 de Febrero	Av. Coronel Gregorio Méndez Magaña	4094.537	1637.815	280	3958.96	50358.02	17220.03	5005	23240	3166.1	135.69	103083.8	140
221	SEDESOL	Reforma 126	552.832	221.1328	37	534.5268	6654.453	2275.503	643.5	3071	407.07	45.23	13631.28	18.5
222	Normal de Educación FÍsica Pablo GarcÍa ┴valos	Velódromo Cd. Deportiva	5887.824	2355.13	403	5692.868	72479.58	24784.54	7150	33449	4523	226.15	148305.1	201.5
223	Técnica 1	Av. H. Colegio Militar	4927.73	1971.092	337	4764.565	60609.48	20725.53	6006	27971	3799.32	180.92	124056.8	168.5
224	SEDESOL	Altamira	2322.719	929.0876	159	2245.81	28596.16	9778.514	2788.5	13197	1763.97	90.46	58460.42	79.5
225	GetsemanÍ (SEDESOL)	Zapotal	1288.271	515.3084	88	1245.614	15826.81	5412.008	1573	7304	995.06	45.23	32401.72	44
226	Pablo Montesino	2¬ Cda. de I. Manuel Altamirano	3872.938	1549.175	265	3744.699	47660.27	16297.52	4719	21995	2985.18	135.69	97537.36	132.5
227	Leo Kanner	Av. Coronel Gregorio Méndez Magaña	9158.803	3663.521	628	8855.54	112945.8	38622.06	11225.5	52124	7101.11	316.61	231190.7	314
228	Técnica 11	Revolución, esq. con Marcelino GarcÍa Barragán	24612.84	9845.136	1687	23797.87	303407.1	103750.7	30101.5	140021	19041.83	768.91	620888.8	843.5
229	Carmen Cadena de BuendÍa	Melchor Ocampo	4711.545	1884.618	323	4555.538	58091.57	19864.53	5720	26809	3618.4	180.92	118840	161.5
230	Corte y Confección y Cultura de Belleza	Revolución	330.258	132.1032	22	319.3226	3956.702	1353.002	357.5	1826	226.15	45.23	8083.906	11
231	UVM	Av. México	36261.25	14504.5	2486	35060.58	447107.3	152889.2	44401.5	206338	28087.83	1130.75	915015.2	1243
232	OrquÍdea	Calle Frontón	781.59	312.636	53	755.7103	9532.054	3259.505	929.5	4399	587.99	45.23	19508.99	26.5

233	Yo soy El Gran Jesucristo	Maratón	603.438	241.3752	41	583.4572	7373.853	2521.504	715	3403	452.3	45.23	15094.34	20.5
234	GuarderÍa SEDESOL	Ejido	725.754	290.3016	49	701.7231	8812.654	3013.504	858	4067	542.76	45.23	18040.87	24.5
235	Puerta de Salvación	Campesino	561.992	224.7968	38	543.3835	6834.303	2337.003	643.5	3154	407.07	45.23	13964.49	19
236	Ramón Mendoza	Calle Independencia, esq. con Anacleto Canabal	3736.777	1494.711	256	3613.046	46041.62	15744.02	4576	21248	2894.72	135.69	94253.1	128
237	Monte de Sión	Anacleto Canabal, esq. con Av. 16 de Septiembre	1161.609	464.6436	79	1123.146	14208.16	4858.507	1358.5	6557	859.37	45.23	29009.91	39.5
238	Jesucristo El Señor	C. José Moreno Irabién, esq. con Av. 16 de Septiembre	296.641	118.6564	20	286.8187	3597.002	1230.002	357.5	1660	226.15	45.23	7402.702	10
239	Mormona	Av. 27 de Febrero, casi esq. con Calle Ceiba	1240.18	496.072	85	1199.116	15287.26	5227.508	1501.5	7055	949.83	45.23	31265.44	42.5
240	ISSSTE	Andrés GarcÍa, esq. con 16 de Septiembre	4528.213	1811.285	310	4378.276	55753.52	19065.03	5505.5	25730	3482.71	180.92	114096	155
241	Jacobo Vázquez	José Moreno Irabién, entre Independencia y Periodista	1179.76	471.904	80	1140.696	14388.01	4920.007	1430	6640	904.6	45.23	29468.54	40
242	Guadalupe MartÍnez	Calle Ceiba, entre Roberto Ruiz y Cda. La Ceiba	2593.469	1037.388	177	2507.595	31833.46	10885.52	3146	14691	1990.12	90.46	65144.15	88.5
243	GuarderÍa	Av. QuintÍn Arauz, esq. con La pigua	295.459	118.1836	20	285.6759	3597.002	1230.002	357.5	1660	226.15	45.23	7401.559	10
244	Cendi 3	Calle Ceiba, entre Manuel Téllez y QuintÍn Arauz	4008.277	1603.311	274	3875.556	49278.92	16851.02	4862	22742	3075.64	135.69	100820.8	137
245	Federico Froebel	Antonio de Quevedo, casi esq. con Av. César Sandino	1491.773	596.7092	102	1442.378	18344.71	6273.009	1787.5	8466	1130.75	90.46	37534.81	51
246	El Nazareno	Melchor Ocampo, casi esq. con Calle 1	367.002	146.8008	25	354.85	4496.252	1537.502	429	2075	271.38	45.23	9209.214	12.5
247	Adventista del 7º DÍa	Profa. J. Claro, esq con Profa. Rosa Moguel	537.129	214.8516	36	519.3438	6474.603	2214.003	643.5	2988	407.07	45.23	13291.75	18
248	Régulo Torpey Andrade	Guaymas, casi esq. con Laguna de Las Ilusiones	596.504	238.6016	40	576.7528	7194.003	2460.004	715	3320	452.3	45.23	14763.29	20
249	Del Bosque	Guayacán, esq. con Tatuán	303.773	121.5092	20	293.7146	3597.002	1230.002	357.5	1660	226.15	45.23	7409.598	10
250	Concepción Nelly GarcÍa	Calle 4	1858.285	743.314	127	1796.754	22840.96	7810.512	2216.5	10541	1402.13	90.46	46698.32	63.5
251	CBTIS 163	Revolución	15449.82	6179.93	1059	14938.25	190461.2	65128.6	18876	87897	11940.72	497.53	389739.3	529.5
252	Beatriz Zentella de T.	Laguna de Las Ilusiones, entre Tampico y Matamoros	591.203	236.4812	40	571.6273	7194.003	2460.004	715	3320	452.3	45.23	14758.16	20
253	Jahdal	Anacleto Canabal, entre Av. 16 de Septiembre y Periodista	3803.365	1521.346	260	3677.429	46761.02	15990.02	4647.5	21580	2939.95	135.69	95731.61	130
254	Montessori	José Moreno Irabién, casi esq. con Av. 16 de Septiembre	944.258	377.7032	64	912.992	11510.4	3936.006	1144	5312	723.68	45.23	23584.31	32
255	Crayolitas	Av. César Sandino, entre Independencia y Manuel Téllez	304.912	121.9648	20	294.8159	3597.002	1230.002	357.5	1660	226.15	45.23	7410.699	10
256	Cristiano	Andrés GarcÍa, esq. con Edmundo Zetina	570.029	228.0116	39	551.1544	7014.153	2398.504	643.5	3237	407.07	45.23	14296.61	19.5
257	La Lupita	José Moreno Irabién, esq. con Independencia	297.756	119.1024	20	287.8968	3597.002	1230.002	357.5	1660	226.15	45.23	7403.78	10
258	Casa del Voluntariado	Laguna de Las Ilusiones, entre Cástulo Trejo y Guaymas	4514.707	1805.883	309	4365.218	55573.67	19003.53	5505.5	25647	3482.71	180.92	113758.5	154.5

259	Cristiano	Dr. Régulo Torpey No. 4, entre Mario Brown P. y Ernestina Montes	365.883	146.3532	25	353.768	4496.252	1537.502	429	2075	271.38	45.23	9208.132	12.5
260	UJAT (Facultad de Medicina)	Coronel Gregorio Méndez, esq. con And. Escuela de Medicina	46455.6	3280	562	7928.484	101075.7	34563.05	10010	46646	6332.2	271.38	206826.9	281
261	Jes·s Sibilla Zurita	Laguna del Espejo y Laguna de Covadonga	1217.367	486.9468	83	1177.058	14927.56	5104.508	1430	6889	904.6	45.23	30477.95	41.5
262	Tecnológico 28	Choco Tabasqueño	11665.29	4666.115	799	11279.03	143700.2	49138.57	14228.5	66317	9000.77	361.84	294025.9	399.5
263	IDEFTAB	Malecón Leandro Rovirosa Wade	3919.174	1567.67	268	3789.404	48199.82	16482.02	4790.5	22244	3030.41	135.69	98671.85	134
264	Cendi Carmen V. de Mora	Manuel Arrazola	2738.752	1095.501	187	2648.067	33631.96	11500.52	3289	15521	2080.58	90.46	68761.59	93.5
265	Wenseslao Reyes Pérez	Pepe del Rivero	3141.637	1256.655	215	3037.612	38667.77	13222.52	3789.5	17845	2397.19	135.69	79095.28	107.5
266	INEA. SEAD.	Malecón Leandro Rovirosa Wade, esq. con Manuel Arrazola	1330.371	532.1484	91	1286.32	16366.36	5596.508	1573	7553	995.06	45.23	33415.48	45.5
267	Técnica 47	Calle 8	15685.43	6274.17	1075	15166.06	193338.8	66112.6	19162	89225	12121.64	497.53	395623.7	537.5
268	Maranatha	Laguna La Pólvora	457.295	182.918	31	442.1532	5575.352	1906.503	500.5	2573	316.61	45.23	11359.35	15.5
269	CAPECE	Calle 11	4470.068	1788.027	306	4322.057	55034.12	18819.03	5434	25398	3437.48	180.92	112625.6	153
270	Candelaria Flores	Antonio Reyes Zurita, esq. con C. Arcoiris	4997.338	1998.935	342	4831.868	61508.73	21033.03	6077.5	28386	3844.55	180.92	125862.6	171
271	GetsemanÍ	Antonio Reyes Zurita	778.514	311.4056	53	752.7361	9532.054	3259.505	929.5	4399	587.99	45.23	19506.02	26.5
272	Testigos de Jehová	Antonio Reyes Zurita	359.174	143.6696	24	347.2811	4316.402	1476.002	429	1992	271.38	45.23	8877.295	12
273	Colegio Americano de Tabasco	Av. Paseo Usumacinta, esq. con Prol. 27 de Febrero	19816.86	7926.744	1358	19160.69	244236.4	83517.12	24238.5	112714	15332.97	633.22	499832.9	679
274	Educación Especial ┌NETE	Ignacio Zaragoza	605.348	242.1392	41	585.3039	7373.853	2521.504	715	3403	452.3	45.23	15096.19	20.5
275	Carlos Rovirosa Pérez	Av. 27 de Febrero, esq. con Rayón	454.521	181.8084	31	439.4711	5575.352	1906.503	500.5	2573	316.61	45.23	11356.67	15.5
276	Academia de Belleza	Cda. Tlaxcala	999.166	399.6664	68	966.0819	12229.81	4182.006	1215.5	5644	768.91	45.23	25051.53	34
277	JardÍn de Niños Rosaura Zapata	Ignacio Zaragoza, esq. con Cuitláhuac	1337.73	535.092	91	1293.436	16366.36	5596.508	1573	7553	995.06	45.23	33422.59	45.5
278	P. José Ochoa Lobato, Simón Sarlat Nova	Plutarco ElÍas Calles	2461.605	984.642	168	2380.097	30214.81	10332.02	3003	13944	1899.66	90.46	61864.05	84
279	Cendi Chapultepec	Plutarco ElÍas Calles	591.596	236.6384	40	572.0073	7194.003	2460.004	715	3320	452.3	45.23	14758.54	20
280	BenjamÍn Franklin	Margarita Maza de Juárez GarcÍa	2418.82	967.528	165	2338.729	29675.26	10147.52	2931.5	13695	1854.43	90.46	60732.9	82.5
281	Universidad Interamericana del Norte	Paseo Tabasco	5655.799	2262.32	387	5468.526	69601.98	23800.54	6864	32121	4342.08	180.92	142379	193.5
282	José Narciso Rovirosa	Reforma, esq. con Calle 4	1535.752	614.3008	105	1484.901	18884.26	6457.51	1859	8715	1175.98	90.46	38667.11	52.5
283	DECROIY	Calle 3	1635.904	654.3616	112	1581.736	20143.21	6888.01	2002	9296	1266.44	90.46	41267.86	56
284	La Iglesia de Dios	Ernesto Malda, esq. con Miguel Hidalgo	321.098	128.4392	22	310.4659	3956.702	1353.002	357.5	1826	226.15	45.23	8075.05	11

285	Dios es Amor	Ernesto Malda, esq. con Miguel Hidalgo	640.098	256.0392	43	618.9033	7733.553	2644.504	715	3569	452.3	45.23	15778.49	21.5
286	Peniel	Reforma	513.826	205.5304	35	496.8124	6294.753	2152.503	572	2905	361.84	45.23	12828.14	17.5
287	Gregorio Méndez Magaña	Aquiles Serdán 304	1401.973	560.7892	96	1355.551	17265.61	5904.009	1716	7968	1085.52	45.23	35339.92	48
288	Ignacio Loyola	Niños Héroes	480.885	192.354	32	464.9621	5755.202	1968.003	572	2656	361.84	45.23	11823.24	16
289	Elpidio López Escobar	Ayuntamiento, casi esq. con Av. 27 de Febrero	7850.391	3140.156	538	7590.451	96759.34	33087.05	9581	44654	6060.82	271.38	198004	269
290	Isabel DÍaz	Ayuntamiento	2372.406	948.9624	162	2293.852	29135.71	9963.015	2860	13446	1809.2	90.46	59598.24	81
291	Centro Escolar 1º de Mayo	Ayuntamiento	8508.676	3403.47	583	8226.94	104852.6	35854.55	10367.5	48389	6558.35	271.38	214520.3	291.5
292	Catedral del Señor de Tabasco	27 de Febrero, esq. con Paseo Tabasco	9393.146	3757.258	644	9082.123	115823.4	39606.06	11511.5	53452	7282.03	316.61	237073.8	322
293	Maranatha	Belisario DomÍnguez	530.906	212.3624	36	513.3268	6474.603	2214.003	643.5	2988	407.07	45.23	13285.73	18
294	José Morga GarcÍa	Ignacio RamÍrez	4341.07	1736.428	297	4197.33	53415.47	18265.53	5291	24651	3347.02	135.69	109303	148.5
295	Centro Universitario de Tabasco	Plutarco ElÍas Calles	1849.766	739.9064	126	1788.517	22661.11	7749.011	2216.5	10458	1402.13	90.46	46365.73	63
296	20 de Noviembre	Lino Merino, esq. con Fco. Javier Mina	7472.592	2989.037	512	7225.162	92083.24	31488.05	9152	42496	5789.44	271.38	188505.3	256
297	Secundaria Federal No. 1 "Jaime Torres Bodet"	Av. Fco. Javier Mina, esq. con A. Sánchez Magallanes	3473.844	1389.538	238	3358.819	42804.32	14637.02	4218.5	19754	2668.57	135.69	87576.92	119
298	Centro de Enseñanza Abierta	Lino Merino, esq. con Domingo Borrego	597.273	238.9092	40	577.4963	7194.003	2460.004	715	3320	452.3	45.23	14764.03	20
299	Idiftec	Av. Coronel Gregorio Méndez Magaña	1496.93	598.772	102	1447.364	18344.71	6273.009	1787.5	8466	1130.75	90.46	37539.79	51
300	Profa. Virgina Pérez Gil	Av. Fco. Javier Mina 911	2997.768	1199.107	205	2898.507	36869.27	12607.52	3646.5	17015	2306.73	135.69	75479.21	102.5
301	De La Conchita		2297.707	919.0828	157	2221.626	28236.46	9655.514	2788.5	13031	1763.97	90.46	57787.53	78.5
302	Señor de Tila	Antonio Rullan Ferrer	423.473	169.3892	29	409.4511	5215.652	1783.503	500.5	2407	316.61	45.23	10677.95	14.5
303	Salón del Reino de Los Testigos de Jehová	Av. 27 de Febrero	708.84	283.536	48	685.3691	8632.804	2952.004	858	3984	542.76	45.23	17700.17	24
304	San Judas Tadeo	Calle 25	1174.211	469.6844	80	1135.331	14388.01	4920.007	1430	6640	904.6	45.23	29463.17	40
305	Cendi 2	Plutarco ElÍas Calles	2299.379	919.7516	157	2223.243	28236.46	9655.514	2788.5	13031	1763.97	90.46	57789.15	78.5
306	Profa. Eneyda Taracena GarcÍa	Domingo Borrego 314	2986.355	1194.542	204	2887.472	36689.42	12546.02	3646.5	16932	2306.73	135.69	75143.83	102
307	Sagrado Corazón	Fernando Montes de Oca	542.633	217.0532	37	524.6655	6654.453	2275.503	643.5	3071	407.07	45.23	13621.42	18.5
308	Birmingham	Ernesto Malda	1062.043	424.8172	72	1026.877	12949.21	4428.007	1287	5976	814.14	45.23	26526.46	36
309	Birmingham	Ernesto Malda	400.002	160.0008	27	386.7573	4855.952	1660.502	429	2241	271.38	45.23	9889.822	13.5
310	Babies and Kids	A. Sánchez Magallanes No. 916	394.438	157.7752	27	381.3775	4855.952	1660.502	429	2241	271.38	45.23	9884.442	13.5
311	Universidad Interamericana del Norte	Av. Coronel Gregorio Méndez, esq. con Olivero Pulido	2816.029	1126.412	193	2722.786	34711.06	11869.52	3432	16019	2171.04	90.46	71015.87	96.5

312	Univeridad CNCI	27 de Febrero, frente a Peredo	1036.426	414.5704	71	1002.108	12769.36	4366.506	1215.5	5893	768.91	45.23	26060.61	35.5
313	Alfonso Caparoso	José MartÍ	562.387	224.9548	38	543.7654	6834.303	2337.003	643.5	3154	407.07	45.23	13964.87	19
314	Testigos de Dios	Calle 25	439.285	175.714	30	424.7395	5395.502	1845.003	500.5	2490	316.61	45.23	11017.58	15
315	Estancia Infantil	José Méndez GarcÍa	349.832	139.9328	23	338.2485	4136.552	1414.502	357.5	1909	226.15	45.23	8427.182	11.5
316	Téc. Sec. 9	Paseo de La Sierra	4755.133	1902.053	326	4597.683	58631.13	20049.03	5791.5	27058	3663.63	180.92	119971.9	163
317	Estancia Burbujas	Paseo de La Sierra	497.361	198.9444	34	480.8925	6114.903	2091.003	572	2822	361.84	45.23	12487.87	17
318	Oasis de Amor	Fco. Javier Mina 98	1512.531	605.0124	103	1462.449	18524.56	6334.509	1787.5	8549	1130.75	90.46	37879.23	51.5
319	Beatriz Ordóñez	Calle 4	1252.482	500.9928	85	1211.01	15287.26	5227.508	1501.5	7055	949.83	45.23	31277.33	42.5
320	HERSOR	Paseo Tabasco, esq. con Calle 4	3772.281	1508.912	258	3647.374	46401.32	15867.02	4576	21414	2894.72	135.69	94936.13	129
321	Birmingham	Ernesto Malda	1132.289	452.9156	77	1094.797	13848.46	4735.507	1358.5	6391	859.37	45.23	28332.86	38.5
322	Cristóbal Colón	Tabasco	420.02	168.008	28	406.1124	5035.802	1722.003	500.5	2324	316.61	45.23	10350.26	14
323	Milagros	Tabasco	452.297	180.9188	31	437.3207	5575.352	1906.503	500.5	2573	316.61	45.23	11354.52	15.5
324	C. Aton. Pinkib	Framboyán	4211.58	1684.632	288	4072.128	51796.82	17712.03	5148	23904	3256.56	135.69	106025.2	144
325	Com. Folklórica de Villahermosa	23 de Agosto	332.014	132.8056	22	321.0205	3956.702	1353.002	357.5	1826	226.15	45.23	8085.604	11
326	Eligio N. Granados	Paseo Usumacinta, casi esq. con Av. 27 de Febrero	12748.1	5099.24	874	12325.99	157189	53751.08	15587	72542	9860.14	407.07	321662.2	437
327	Bachillerato Tec. Municipal	José Ma. Morelos y Pavón	713.055	285.222	48	689.4446	8632.804	2952.004	858	3984	542.76	45.23	17704.24	24
328	Señor de La Salud	Simón Sarlat	737.344	294.9376	50	712.9293	8992.504	3075.005	858	4150	542.76	45.23	18376.43	25
329	Jean Piaget	Av. 27 de Febrero y Reforma	16394.87	6557.947	1124	15852.01	202151.5	69126.1	20091.5	93292	12709.63	542.76	413765.5	562
330	Benito Juárez	Av. 27 de Febrero	5929.723	2371.889	406	5733.38	73019.13	24969.04	7221.5	33698	4568.23	226.15	149435.4	203
331	Mundo Feliz	Niños Héroes 158	3335.906	1334.362	228	3225.449	41005.82	14022.02	4075.5	18924	2578.11	135.69	83966.59	114
332	Señor de Tila	Francisco J. Mujica	505.402	202.1608	34	488.6673	6114.903	2091.003	572	2822	361.84	45.23	12495.64	17
333	Jes·s de Nazareno	Mariano Abasolo, esq. con Buenavista	755.203	302.0812	51	730.197	9172.354	3136.505	858	4233	542.76	45.23	18718.05	25.5
334	Sol de Justicia Pentecostés	Emilio Carranza	1921.955	768.782	131	1858.316	23560.36	8056.512	2288	10873	1447.36	90.46	48174.01	65.5
335	Cendi Eduardo SeguÍn	Emilio Carranza	988.287	395.3148	67	955.5632	12049.96	4120.506	1144	5561	723.68	45.23	24599.93	33.5
336	El Escudo de La Fe	Libertad	343.021	137.2084	23	331.663	4136.552	1414.502	357.5	1909	226.15	45.23	8420.597	11.5
337	El Buen Pastor	José Ma. Morelos y Pavón	577.924	231.1696	39	558.788	7014.153	2398.504	643.5	3237	407.07	45.23	14304.24	19.5
338	Juan Diego	Revolución	434.572	173.8288	29	420.1826	5215.652	1783.503	500.5	2407	316.61	45.23	10688.68	14.5

339	Fidencia Pascacio	Mariano Abasolo	383.607	153.4428	26	370.9051	4676.102	1599.002	429	2158	271.38	45.23	9549.62	13
340	Santos Degollado, Emiliano Zapata	Revolución	4615.127	1846.051	316	4462.312	56832.62	19434.03	5648.5	26228	3573.17	180.92	116359.6	158
341	Leona Vicario	Av. 27 de Febrero	8477.115	3390.846	581	8196.424	104492.9	35731.55	10367.5	48223	6558.35	271.38	213841.1	290.5
342	XXX Zona Militar		65413.55	26165.42	4485	63247.6	806627.6	275827.9	80151.5	372255	50702.83	2035.35	1650848	2242.5
343	Colegio John Langdan Prees	Eduardo Alday Hernández y Av. 27 de Febrero	709.977	283.9908	48	686.4685	8632.804	2952.004	858	3984	542.76	45.23	17701.27	24
344	Federal Manuel Altamirano	Av. 27 de Febrero	938.148	375.2592	64	907.0844	11510.4	3936.006	1144	5312	723.68	45.23	23578.41	32
345	Cendi Calli Tohui, "José Vasconcelos"	Av. 27 de Febrero	853.209	341.2836	58	824.9578	10431.3	3567.005	1001	4814	633.22	45.23	21316.72	29
346	Centro Municipal de Capacitación	José Ma. Morelos y Pavón	630.541	252.2164	43	609.6627	7733.553	2644.504	715	3569	452.3	45.23	15769.25	21.5
347	Cendi 11	Calle MedellÍn, casi esq. con Paseo de La Pigua	4240.018	1696.007	290	4099.624	52156.52	17835.03	5148	24070	3256.56	135.69	106701.4	145
348	Josefa Ortiz de DomÍnguez	Paseo La Pigua, esq. con Calle Usumacinta	20800.03	8320.011	1426	20111.3	256466.2	87699.13	25454	118358	16101.88	678.45	524869	713
349	COBATAB 29	C. Usumacinta, casi esq. con Paseo de La Pigua	14468.58	5787.432	992	13989.5	178411.3	61008.09	17732	82336	11217.04	452.3	365146.2	496
350	Secundaria Federal No. 2	Av. 27 de Febrero, esq. con Primavera	10154.94	4061.976	696	9818.694	125175.7	42804.06	12441	57768	7870.02	316.61	256194	348
351	UJAT		4787.756	1915.102	328	4629.225	58990.83	20172.03	5863	27224	3708.86	180.92	120768.9	164
352	Pentecostés	Prol. Antimonio	362.514	145.0056	24	350.5106	4316.402	1476.002	429	1992	271.38	45.23	8880.525	12
353	De Dios en México	And. Maquilador	679.357	271.7428	46	656.8624	8273.104	2829.004	786.5	3818	497.53	45.23	16906.23	23
354	Adventista del 7º DÍa	And. Esperanza	428.326	171.3304	29	414.1434	5215.652	1783.503	500.5	2407	316.61	45.23	10682.64	14.5
355	Tecnológico 35	Av. Mártires de Cananea	123381.3	10054	1723	24302.74	309881.7	105964.7	30745	143009	19448.9	814.14	634166.1	861.5
356	Caridad Bravo	Prol. Antimonio	5179.66	2071.864	355	5008.153	63846.78	21832.53	6292	29465	3980.24	180.92	130605.6	177.5
357	Magdalena Contreras Millán	Ejido Plátano y Cacao	480.844	192.3376	32	464.9225	5755.202	1968.003	572	2656	361.84	45.23	11823.2	16
358	Graciela Pintado de Madrazo	Malecón Leandro Rovirosa Wade	4438.342	1775.337	304	4291.381	54674.42	18696.03	5434	25232	3437.48	180.92	111946.2	152
359	Emiliano Zapata	Malecón Leandro Rovirosa Wade	1463.217	585.2868	100	1414.767	17985.01	6150.009	1787.5	8300	1130.75	45.23	36813.26	50
360	Monte Mariah	Malecón Leandro Rovirosa Wade	3021.803	1208.721	207	2921.746	37228.97	12730.52	3646.5	17181	2306.73	135.69	76151.15	103.5
361	Los Girasoles (SEDESOL)	Ejido Torno Largo	318.135	127.254	21	307.601	3776.852	1291.502	357.5	1743	226.15	45.23	7747.835	10.5
362	Rosario Castellanos	La Hamaca	718.844	287.5376	49	695.0419	8812.654	3013.504	858	4067	542.76	45.23	18034.19	24.5
363	Colegio Inglés de Villahermosa	Prol. 27 de Febrero	11515.17	4606.07	789	11133.89	141901.7	48523.57	14085.5	65487	8910.31	361.84	290403.8	394.5
364	CESUM	Ceibas	4910.178	1964.071	336	4747.594	60429.63	20664.03	6006	27888	3799.32	180.92	123715.5	168
365	Maestro Tab.	J. Claro GarcÍa	2334.049	933.6196	160	2256.765	28776.01	9840.015	2860	13280	1809.2	90.46	58912.45	80

366	Aurora	J. Claro GarcÍa	781.945	312.778	53	756.0535	9532.054	3259.505	929.5	4399	587.99	45.23	19509.33	26.5
367	Tec. 44	Campo Cunduacán	7978.465	3191.386	547	7714.285	98377.99	33640.55	9724	45401	6151.28	271.38	201280.5	273.5
368	Leonardo Da Vinci	Campo Teapa No. 19	410.621	164.2484	28	397.0247	5035.802	1722.003	500.5	2324	316.61	45.23	10341.17	14
369	Niños Héroes	Jicotea S/N M 80	2443.477	977.3908	167	2362.569	30034.96	10270.52	2931.5	13861	1854.43	90.46	61405.44	83.5
370	J .N. 30 de Abril	Col. M 80	9142.264	3656.906	626	8839.548	112586.1	38499.06	11154	51958	7055.88	316.61	230409.2	313
371	Est. Danza Clásica	MatÍas Pérez Piedra	881.523	352.6092	60	852.3343	10791	3690.005	1072.5	4980	678.45	45.23	22109.52	30
372	Secundaria Federal No. 6	Av. de Los ┴rboles	9904.451	3961.78	679	9576.498	122118.2	41758.56	12083.5	56357	7643.87	316.61	249854.2	339.5
373	Leticia DomÍnguez Pérez	Av. de Las Flores	802.654	321.0616	55	776.0768	9891.754	3382.505	929.5	4565	587.99	45.23	20178.06	27.5
374	Universidad IEU	Campo Sitio Grande 101	607.889	243.1556	41	587.7608	7373.853	2521.504	715	3403	452.3	45.23	15098.65	20.5
375	Colegio Anáhuac	Campo Sitio Grande, esq. con Campo	2867.252	1146.901	196	2772.313	35250.62	12054.02	3503.5	16268	2216.27	90.46	72155.18	98
376	Art.123 José Vasconcelos	Av. Limón	5420.131	2168.052	371	5240.661	66724.38	22816.53	6578	30793	4161.16	180.92	136494.7	185.5
377	EspÍritu Santo	Av. de Los ┴rboles	353.123	141.2492	24	341.4305	4316.402	1476.002	429	1992	271.38	45.23	8871.445	12
378	Jesucristo de Los Santos de Los ┌ltimos DÍas	Paseo La Choca	4684.127	1873.651	321	4529.028	57731.87	19741.53	5720	26643	3618.4	180.92	118164.8	160.5
379	Melani Klein	MatÍas Pérez Piedra	1048.199	419.2796	71	1013.491	12769.36	4366.506	1215.5	5893	768.91	45.23	26071.99	35.5
380	Melani Klein	MatÍas Pérez Piedra	652.928	261.1712	44	631.3085	7913.403	2706.004	786.5	3652	497.53	45.23	16231.98	22
381	Primaria Lázaro Cárdenas	Av. Campo Cunduacán	4300.609	1720.244	294	4158.209	52875.92	18081.03	5219.5	24402	3301.79	135.69	108174.1	147
382	JFH	Blvd. Adolfo Ruiz Cortines	658.555	263.422	45	636.7491	8093.253	2767.504	786.5	3735	497.53	45.23	16561.77	22.5
383	Arnulfo Giorgana GurrÍa	RÍo Mezcalapa	595.395	238.158	40	575.6805	7194.003	2460.004	715	3320	452.3	45.23	14762.22	20
384	Damasco	RÍo Mezcalapa, esq. con Arroyo Negro	313.596	125.4384	21	303.2123	3776.852	1291.502	357.5	1743	226.15	45.23	7743.446	10.5
385	Del EspÍritu Santo	RÍo Mezcalapa	769.73	307.892	52	744.243	9352.204	3198.005	929.5	4316	587.99	45.23	19173.17	26
386	Ernestina Montes Cameco	Cda. El KÍnder	601.176	240.4704	41	581.2701	7373.853	2521.504	715	3403	452.3	45.23	15092.16	20.5
387	José Ma. Pino Suárez	Principal de Pino Suárez, 2¬ Etapa	2766.254	1106.502	189	2674.659	33991.66	11623.52	3360.5	15687	2125.81	90.46	69553.61	94.5
388	RÍos de Agua Viva	Calle 6	349.355	139.742	23	337.7873	4136.552	1414.502	357.5	1909	226.15	45.23	8426.721	11.5
389	San José	Julián Sánchez	330.617	132.2468	22	319.6697	3956.702	1353.002	357.5	1826	226.15	45.23	8084.253	11
390	Adventista del 7º DÍa	Asunción Castellanos No. 114	334.711	133.8844	22	323.6282	3956.702	1353.002	357.5	1826	226.15	45.23	8088.212	11
391	Delfina Grajales	Ramón Mendoza	4148.463	1659.385	284	4011.1	51077.42	17466.03	5076.5	23572	3211.33	135.69	104550.1	142
392	Colegio Golondrina	Prof. Ramón Mendoza Herrera	496.977	198.7908	34	480.5213	6114.903	2091.003	572	2822	361.84	45.23	12487.5	17

393	Santa Cruz	Principal de Pino Suárez, 1¬ Etapa	435.813	174.3252	29	421.3825	5215.652	1783.503	500.5	2407	316.61	45.23	10689.88	14.5
394	Jes·s Reyes H.	Matilde Pérez FarÍas	8173.096	3269.238	560	7902.471	100716	34440.05	10010	46480	6332.2	271.38	206152.1	280
395	Sup. Edu. Esp.	RÍo Mezcalapa 307	2740.521	1096.208	187	2649.778	33631.96	11500.52	3289	15521	2080.58	90.46	68763.3	93.5
396	Amelia Glez. M.	RÍo Mezcalapa	2741.721	1096.688	188	2650.938	33811.81	11562.02	3360.5	15604	2125.81	90.46	69205.54	94
397	G. D. I. José Ma. Pino Suárez	RÍo Mezcalapa	3155.158	1262.063	216	3050.685	38847.62	13284.02	3861	17928	2442.42	135.69	79549.43	108
398	Universidad Pedagógica Nacional	RÍo Usumacinta	9968.682	3987.473	683	9638.602	122837.6	42004.56	12155	56689	7689.1	316.61	251330.5	341.5
399	Tabasco Avanza	RÍo de La Sierra	532.861	213.1444	36	515.2171	6474.603	2214.003	643.5	2988	407.07	45.23	13287.62	18
400	Nuestra Señora de La Candelaria	Gerónimo Palacios	2164.258	865.7032	148	2092.596	26617.81	9102.013	2645.5	12284	1673.51	90.46	54505.89	74
401	Fuego Pentecostés	Peri	354.883	141.9532	24	343.1322	4316.402	1476.002	429	1992	271.38	45.23	8873.146	12
402	USAER	Tenochtitlan	1737.498	694.9992	119	1679.967	21402.16	7318.511	2073.5	9877	1311.67	90.46	43753.27	59.5
403	Militarizada	Paseo de Las Flores	1415.631	566.2524	97	1368.757	17445.46	5965.509	1716	8051	1085.52	45.23	35677.47	48.5
404	Los ┴ngeles	Paseo de Las Flores	1293.424	517.3696	88	1250.597	15826.81	5412.008	1573	7304	995.06	45.23	32406.7	44
405	Gabriela P. M.	Tenochtitlan	703.707	281.4828	48	680.4061	8632.804	2952.004	858	3984	542.76	45.23	17695.2	24
406	Josefina de Los Santos	Paseo de Las Flores	585.031	234.0124	40	565.6596	7194.003	2460.004	715	3320	452.3	45.23	14752.2	20
407	Sotavento	Priv. Golondrinas	1361.055	544.422	93	1315.988	16726.06	5719.508	1644.5	7719	1040.29	45.23	34210.57	46.5
408	CEI No.1	Paseo de Las Flores	1718.959	687.5836	117	1662.041	21042.46	7195.511	2073.5	9711	1311.67	90.46	43086.64	58.5
409	Carmen MarÍa	Tenochtitlan	2019.643	807.8572	138	1952.769	24819.31	8487.013	2431	11454	1537.82	90.46	50772.37	69
410	COBATAB 28	Paseo de Las Flores	584.322	233.7288	40	564.9741	7194.003	2460.004	715	3320	452.3	45.23	14751.51	20
411	DIF Albergue	Macayo	1650.881	660.3524	113	1596.218	20323.06	6949.51	2002	9379	1266.44	90.46	41606.69	56.5
412	DIF Casa Hogar	Priv. Macayo	1831.049	732.4196	125	1770.42	22481.26	7687.511	2216.5	10375	1402.13	90.46	46023.28	62.5
413	Universidad de S	Priv. Golondrinas	617.061	246.8244	42	596.6291	7553.703	2583.004	715	3486	452.3	45.23	15431.87	21
414	Salón del Reino de Los Testigos de Jehová	Matilde Pérez FarÍas	294.053	117.6212	20	284.3164	3597.002	1230.002	357.5	1660	226.15	45.23	7400.2	10
415	San Pablo Prebisteriana	Matilde Pérez FarÍas	908.736	363.4944	62	878.6462	11150.7	3813.006	1072.5	5146	678.45	45.23	22784.54	31
416	Jehová es Mi Roca	And. 6	315.412	126.1648	21	304.9682	3776.852	1291.502	357.5	1743	226.15	45.23	7745.202	10.5
417	Jes·s El MesÍas (Pentecostés)	2¬ Cda. Asunción Castellanos	326.113	130.4452	22	315.3149	3956.702	1353.002	357.5	1826	226.15	45.23	8079.899	11
418	KINDER KIDS ARBOLEDAS	Av. Dr. Lamberto Castellanos	806.762	322.7048	55	780.0488	9891.754	3382.505	929.5	4565	587.99	45.23	20182.03	27.5
419	Ma. Gamas	Estatuto JurÍdico, esq. con Sindicato de Agricultura	2034.791	813.9164	139	1967.416	24999.16	8548.513	2431	11537	1537.82	90.46	51111.37	69.5

420	Harmon Hall	Av. Dr. Lamberto Castellanos No. 204 Altos	2306.809	922.7236	158	2230.427	28416.31	9717.014	2788.5	13114	1763.97	90.46	58120.68	79
421	Juega y Aprende	Sindicato Hidráulico	395.609	158.2436	27	382.5097	4855.952	1660.502	429	2241	271.38	45.23	9885.574	13.5
422	Jes·s Buen Pastor	RÍo Tacotalpa, esq. con And. RÍo Concordia	315.025	126.01	21	304.594	3776.852	1291.502	357.5	1743	226.15	45.23	7744.828	10.5
423	Católica del Señor	Andrés Quintana Roo	760.62	304.248	52	735.4346	9352.204	3198.005	929.5	4316	587.99	45.23	19164.36	26
424	Carolina DomÍnguez Sosa	Calle 25	2567.636	1027.054	176	2482.617	31653.61	10824.02	3146	14608	1990.12	90.46	64794.83	88
425	Fausto Méndez Jiménez	La Carpa	3085.736	1234.294	211	2983.562	37948.37	12976.52	3718	17513	2351.96	135.69	77627.1	105.5
426	Miguel Hidalgo y Costilla, Fco. Glez. Bocanegra	Buenavista	12920.87	5168.346	886	12493.03	159347.2	54489.08	15801.5	73538	9995.83	407.07	326071.7	443
427	San Felipe de Jes·s	Calle I. Sicilias	483.5	193.4	33	467.4905	5935.053	2029.503	572	2739	361.84	45.23	12150.12	16.5
428	San Judas Tadeo	Calle 5, esq. con Calle 2	1157.328	462.9312	79	1119.007	14208.16	4858.507	1358.5	6557	859.37	45.23	29005.77	39.5
429	Concepción Glez. Naranjo	Andrés Quintana Roo	1842.911	737.1644	126	1781.889	22661.11	7749.011	2216.5	10458	1402.13	90.46	46359.1	63
430	Hábitab	Andrés Quintana Roo	1919.1	767.64	131	1855.555	23560.36	8056.512	2288	10873	1447.36	90.46	48171.25	65.5
431	Viloleta Trujillo	Calle 5	1939.406	775.7624	132	1875.189	23740.21	8118.012	2359.5	10956	1492.59	90.46	48631.96	66
432	Casa de Muñecos	Calle 1	695.412	278.1648	47	672.3857	8452.954	2890.504	786.5	3901	497.53	45.23	17246.1	23.5
433	Emiliano Zapata	Av. del Palmar	6161.379	2464.552	422	5957.365	75896.73	25953.04	7507.5	35026	4749.15	226.15	155315.9	211
434	Manuel Campos Payro	Av. del Palmar	3773.836	1509.534	258	3648.878	46401.32	15867.02	4576	21414	2894.72	135.69	94937.63	129
435	Supervisión Escolar	And. de la Guaya	6348.15	2539.26	435	6137.952	78234.78	26752.54	7722	36105	4884.84	226.15	160063.3	217.5
436	Colegio Cedros	Priv. Cedros	870.83	348.332	59	841.9954	10611.15	3628.505	1001	4897	633.22	45.23	21658.11	29.5
437	Luis Donaldo Colosio	S/N	1846.248	738.4992	126	1785.116	22661.11	7749.011	2216.5	10458	1402.13	90.46	46362.33	63
438	Betania	Tenosique	307.17	122.868	21	296.9991	3776.852	1291.502	357.5	1743	226.15	45.23	7737.233	10.5
439	Sor Juana Inés de La Cruz	Hermenegildo Galeana	8291.688	3316.675	568	8017.136	102154.8	34932.05	10153	47144	6422.66	271.38	209095.1	284
440	Luz C. de La Cruz Saloya	Av. Olmeca	3496.946	1398.778	239	3381.156	42984.17	14698.52	4218.5	19837	2668.57	135.69	87923.61	119.5
441	Insurgentes	Abrazo de Acatempan	21598.76	8639.503	1481	20883.59	266358	91081.63	26455	122923	16735.1	678.45	545114.7	740.5
442	Universidad Juárez Autónoma de Tabasco		68626.11	27450.44	4705	66353.78	846194.6	289357.9	84084	390515	53190.48	2171.04	1731867	2352.5
443	Universidad Juárez Autónoma de Tabasco		33277.39	13310.96	2281	32175.52	410238	140281.7	40755	189323	25781.1	1040.29	839594.6	1140.5

Finally, the DCs available for the city of Villahermosa are presented on Table D.6.

Table D.6. Available DCs in Villahermosa

ID	Name	Location	Source location	Indoors area (m^2)	Estimated capacity (m3)	Cleaning cost (MXP)
A	CEMAGRO	Av. Cobre	MOSILTRA	5275	6330	12750.84
B	CEMATAB	Av. Cobre	MOSILTRA	4900	5880	11844.38
C	Bodega Diconsa	Av. Aluminio	MOSILTRA	5400	6480	13052.99
D	Seguro Popular	Macayo	MOSILTRA	1790	2148	4326.825
E	JosΘ Ma. Pino Suárez	PerifΘrico Carlos Pellicer Cámara	MOSILTRA	3295	3954	7964.743
F	Centro Pensionado del ISSSTE	Sindicato de Marina	MOSILTRA	594	712.8	1435.829
G	Librerφa SEP	Zona CICOM	MOSILTRA	2235	2682	5402.489
H	XXX Zona Militar		MOSILTRA	2989	3586.8	7225.073
I	PRI Estatal	Av. 16 de Septiembre, casi esq. con CΘsar Sandino	MOSILTRA	1470	1764	3553.315
J	Bomberos	PerifΘrico Carlos Pellicer Cámara, esq. con 16 de Septiembre	MOSILTRA	430	516	1039.405
K	DIF Defensa del Menor	Anacleto Canabal, casi esq. con PefifΘrico Carlos Pellicer Cámara	MOSILTRA	1944	2332.8	4699.077
L	Secretarφa de Desarrollo Social	Privada del Caminero 17, Col. 1° de Mayo	SEDESOL	1872	2246.4	4525.037
M	Centro del Maestro	Tiro	MOSILTRA	2130	2556	5148.68
N	Hangar del Gobierno del Estado de Tabasco	Aeropuerto Internacional de Villahermosa, Tab.	SEDENA	1710	2052	4133.448
O	DINA (AUTOTAB, antes "Mercedez Benz")	Periférico, a la altura de la Bodega "Corona"	SEDENA	2240	2688	5414.575
P	Bodega "Gigante"	Calle Ruiz Cortinez S/N	SEDENA	612	734.4	1479.339
Q	Ciudad Deportiva	Av. Heroico Colegio Militar y Circuito Deportivo	SEDENA	1200	1440	2900.665
R	Bodega de Gobierno 1	Periférico Carlos Pellicer Cámara S/N, a un costado de la Mercedez Benz	DICONSA, PC	12800	15360	30940.43
S	Bodega de Gobierno 2	Avenida Ruiz Cortines	DICONSA	1500	1800	3625.831
T	Bodega de Gobierno 3	Nave 2 del Parque Tabasco	DICONSA	5750	6900	13899.02
U	Centro de Distribución Parque Tabasco Nave 3	Nave 3 del Parque Tabasco, R/a Emiliano Zapata	PC	6442	7730.4	15571.74
V	Bodega de Distribución de PC 2007	Kilómetro 4 Carretera Villahermosa-Frontera, Calle Cobre S/N, Ciudad Industrial	PC	6768	8121.6	16359.75

APPENDIX E. RESULTS FROM THE GIS FOR THE THREE CASE STUDIES

Veracruz

After the application of the macro on IDRISI different results can be obtained. Table E.1 shows the availability of shelters for the three scenarios established on Veracruz, displaying overall a low number of facilities at risk.

Table E.1. Candidate shelters for the three scenarios in Veracruz

Shelter	0.5 meters	1.5 meters	2.5 meters	Shelter	0.5 meters	1.5 meters	2.5 meters
1	1	1	1	23	1	1	1
2	1	1	1	24	1	1	1
3	1	1	1	25	1	1	1
4	1	1	0	26	1	1	1
5	1	1	1	27	1	1	1
6	1	1	0	28	1	1	1
7	1	0	0	29	1	1	1
8	1	1	1	30	1	1	1
9	1	1	1	31	1	1	1
10	1	1	1	32	0	0	0
11	1	1	0	33	1	1	1
12	1	1	1	34	1	1	1
13	1	1	1	35	1	1	1
14	1	1	1	36	1	1	1
15	1	1	1	37	1	1	1
16	1	1	1	38	1	1	1
17	1	1	1	39	1	1	1
18	1	1	1	40	1	1	1
19	1	1	1	41	1	1	1

20	1	1	1	42	1	1	1
21	1	1	1	43	1	1	1
22	1	1	1	44	1	0	0

Similarly, Table E.2 displays the facilities available to operate as distribution centres under the three scenarios.

Table E.2. Candidate distribution centres for the three scenarios in Veracruz

DC	0.5 meters	1.5 meters	2.5 meters	DC	0.5 meters	1.5 meters	2.5 meters
A	0	0	0	F	1	1	1
B	1	1	1	G	1	1	1
C	1	1	1	H	1	1	1
D	1	1	1	I	1	1	1
E	1	1	0	J	1	1	1

Regarding the demand areas, Table E.3 shows the level of damage caused by the floods on each one of the AGEBs. This level of damage was estimated as follows: $Damage = \frac{A_i - A_f}{A_i} * 100\%$; being A_i the initial area without the flood and A_f the final dry area after the flood.

Table E.3. Damage to the AGEBS for the three scenarios in Veracruz

AGEB	0.5 m	1.5 m	2.5 m	*AGEB*	0.5 m	1.5 m	2.5 m	*AGEB*	0.5 m	1.5 m	2.5 m	*AGEB*	0.5 m	1.5 m	2.5 m
1	0.0	0.0	0.0	*80*	78.1	84.4	90.6	*159*	0.0	0.0	0.0	*238*	0.0	0.0	0.0
2	45.0	58.7	69.7	*81*	100	100	100	*160*	0.0	0.0	0.0	*239*	0.0	0.0	0.0
3	0.0	1.5	4.4	*82*	100	100	100	*161*	0.0	0.0	0.0	*240*	0.0	0.0	0.0
4	5.4	8.9	10.7	*83*	40.0	40.0	60.0	*162*	0.0	0.0	0.0	*241*	0.0	0.0	0.0
5	0.0	0.0	87.5	*84*	0.0	0.0	0.0	*163*	0.0	0.0	0.0	*242*	0.0	0.0	0.0
6	0.0	0.8	1.5	*85*	0.0	0.0	0.0	*164*	100	100	100	*243*	0.0	0.0	0.0

7	0.0	0.0	0.0	*86*	0.0	0.0	3.4	*165*	0.0	0.0	0.0	*244*	2.0	2.0	4.1
8	7.1	9.5	11.9	*87*	0.0	0.0	0.0	*166*	0.0	0.0	0.0	*245*	0.0	0.0	2.2
9	0.0	4.3	13.0	*88*	10.3	31.0	72.4	*167*	0.0	0.0	0.0	*246*	1.5	13.8	23.1
10	61.1	80.6	94.4	*89*	0.0	0.0	1.9	*168*	0.0	0.0	0.0	*247*	0.0	0.0	6.1
11	91.7	100	100	*90*	4.1	10.2	32.7	*169*	0.0	0.0	0.0	*248*	2.8	4.2	19.7
12	39.3	67.9	89.3	*91*	34.5	56.0	79.8	*170*	0.0	0.0	0.0	*249*	0.0	0.0	0.0
13	87.1	100	100	*92*	0.0	0.0	2.7	*171*	0.0	0.0	0.0	*250*	0.0	0.0	0.0
14	0.0	0.0	0.0	*93*	2.5	2.5	7.5	*172*	0.0	0.0	0.0	*251*	0.0	0.0	0.0
15	0.0	0.0	0.0	*94*	0.0	8.8	17.6	*173*	0.0	0.0	0.0	*252*	0.0	0.0	0.0
16	0.0	0.0	0.0	*95*	0.0	0.0	0.0	*174*	0.0	0.0	0.0	*253*	0.0	0.0	0.0
17	0.0	0.0	0.0	*96*	0.0	0.0	2.0	*175*	0.0	0.0	0.0	*254*	0.0	0.0	0.0
18	0.0	0.0	0.0	*97*	15.8	21.1	55.3	*176*	0.0	0.0	0.0	*255*	0.0	0.0	0.0
19	0.0	0.0	0.0	*98*	0.0	0.0	3.4	*177*	0.0	0.0	0.0	*256*	0.0	0.0	0.0
20	0.0	0.0	0.0	*99*	0.0	0.0	0.0	*178*	0.0	0.0	0.0	*257*	0.0	0.0	0.0
21	0.0	0.0	0.0	*100*	0.0	0.0	0.0	*179*	0.0	0.0	0.0	*258*	0.0	0.0	0.0
22	0.0	0.0	0.0	*101*	0.0	0.0	0.0	*180*	0.0	0.0	0.0	*259*	0.0	0.0	0.0
23	0.0	0.0	0.0	*102*	0.0	0.0	0.0	*181*	0.0	0.0	0.0	*260*	0.0	0.0	0.0
24	0.0	0.0	0.0	*103*	0.0	0.0	0.0	*182*	0.0	0.0	0.0	*261*	0.0	0.0	0.0
25	0.0	0.0	0.0	*104*	0.0	0.0	0.0	*183*	100	100	100	*262*	0.0	0.0	0.0
26	0.0	0.0	0.0	*105*	0.0	0.0	0.0	*184*	0.0	0.0	0.0	*263*	0.0	0.0	0.0
27	0.0	0.0	0.0	*106*	0.0	0.0	0.0	*185*	0.0	0.0	0.0	*264*	0.0	0.0	0.0
28	0.0	0.0	0.0	*107*	0.0	0.0	1.9	*186*	0.0	0.0	0.0	*265*	0.0	0.0	0.0
29	0.0	0.0	0.0	*108*	0.0	0.0	0.0	*187*	23.5	35.3	58.8	*266*	0.0	0.0	0.0
30	0.0	0.0	0.0	*109*	0.0	0.0	0.0	*188*	13.3	20.0	40.0	*267*	0.0	0.0	0.0
31	0.0	0.0	0.0	*110*	0.0	0.0	0.0	*189*	10.0	35.0	45.0	*268*	0.0	0.0	0.0
32	0.0	0.0	0.0	*111*	7.6	32.9	70.9	*190*	11.1	14.8	33.3	*269*	0.0	0.0	0.0
33	0.0	0.0	0.0	*112*	0.0	0.0	3.2	*191*	35.9	56.4	79.5	*270*	0.0	0.0	0.0

34	0.0	0.0	0.0	*113*	9.4	43.8	71.9	*192*	11.1	22.2	88.9	*271*	14.3	14.3	28.6
35	0.0	0.0	0.0	*114*	11.8	31.4	72.5	*193*	0.0	0.0	0.0	*272*	26.4	45.3	60.4
36	0.0	0.0	0.0	*115*	0.0	0.0	0.0	*194*	21.7	43.5	45.7	*273*	3.9	13.7	37.3
37	0.0	0.0	0.0	*116*	0.0	0.0	0.0	*195*	47.9	54.3	57.5	*274*	0.0	0.0	0.0
38	0.0	0.0	0.0	*117*	0.0	0.0	5.6	*196*	0.0	0.0	0.0	*275*	0.0	0.0	7.4
39	0.0	0.0	0.0	*118*	0.0	0.0	0.0	*197*	0.0	0.0	5.5	*276*	0.0	6.9	10.3
40	0.0	0.0	0.0	*119*	28.9	71.1	86.7	*198*	0.0	0.0	0.0	*277*	0.0	0.0	0.0
41	0.0	0.0	0.0	*120*	0.0	0.0	0.0	*199*	8.3	25.0	25.0	*278*	0.0	0.0	0.0
42	0.0	0.0	0.0	*121*	0.0	0.0	0.0	*200*	33.3	66.7	66.7	*279*	12.2	29.3	31.7
43	0.0	0.0	0.0	*122*	0.0	0.0	0.0	*201*	0.0	0.0	32.0	*280*	5.2	9.5	16.4
44	0.0	0.0	0.0	*123*	0.0	0.0	0.0	*202*	0.0	0.0	0.0	*281*	0.0	1.2	2.4
45	0.0	0.0	0.0	*124*	0.0	0.0	0.0	*203*	0.0	0.0	0.0	*282*	2.4	2.4	11.9
46	0.0	0.0	0.0	*125*	54.0	66.0	78.5	*204*	0.0	0.0	0.0	*283*	0.0	0.0	1.5
47	0.0	0.0	0.0	*126*	7.7	11.5	23.1	*205*	6.3	6.3	12.5	*284*	0.0	0.0	0.0
48	0.0	0.0	0.0	*127*	25.3	44.8	62.1	*206*	0.0	0.0	0.0	*285*	0.0	0.0	4.1
49	0.0	0.0	0.0	*128*	36.6	51.3	65.4	*207*	0.0	0.0	0.0	*286*	0.0	0.0	0.0
50	0.0	0.0	0.0	*129*	0.0	0.0	0.0	*208*	0.0	0.0	0.0	*287*	0.0	4.7	20.9
51	0.0	0.0	0.0	*130*	0.0	0.0	0.0	*209*	0.0	0.0	0.0	*288*	0.0	0.0	0.0
52	0.0	0.0	0.0	*131*	0.0	0.0	0.0	*210*	0.0	0.0	0.0	*289*	0.0	0.0	0.0
53	0.0	0.0	0.0	*132*	0.0	0.0	0.0	*211*	0.0	0.0	0.0	*290*	0.0	0.0	0.0
54	0.0	0.0	0.0	*133*	0.0	0.0	0.0	*212*	0.0	0.0	0.0	*291*	0.0	0.0	0.0
55	0.0	0.0	0.0	*134*	23.6	30.9	36.4	*213*	0.0	0.0	0.0	*292*	0.0	0.0	0.0
56	0.0	0.0	0.0	*135*	0.0	0.0	0.0	*214*	0.0	0.0	0.0	*293*	3.8	3.8	3.8
57	0.0	0.0	0.0	*136*	0.0	0.0	0.0	*215*	0.0	0.0	0.0	*294*	0.0	0.0	0.0
58	0.0	0.0	0.0	*137*	0.0	0.0	0.0	*216*	0.0	0.0	0.0	*295*	0.0	0.0	0.0
59	0.0	0.0	0.0	*138*	0.0	0.0	0.0	*217*	0.0	0.0	0.0	*296*	0.0	0.0	0.0
60	0.0	0.0	0.0	*139*	0.0	0.0	0.0	*218*	2.4	2.4	2.4	*297*	0.0	6.1	9.1

61	0.0	0.0	0.0	*140*	0.0	0.0	0.0	*219*	0.0	0.0	0.0	*298*	0.0	0.0	0.0
62	0.0	0.0	0.0	*141*	0.0	0.0	0.0	*220*	0.0	0.0	0.0	*299*	12.5	20.5	30.7
63	9.0	15.4	25.6	*142*	0.0	0.0	0.0	*221*	0.0	0.0	0.0	*300*	0.0	15.4	30.8
64	4.7	18.8	42.2	*143*	0.0	0.0	0.0	*222*	0.0	0.0	0.0	*301*	#N/A	#N/A	#N/A
65	7.7	11.5	26.9	*144*	0.0	0.0	0.0	*223*	0.0	0.0	0.0	*302*	0.0	50.0	50.0
66	23.4	34.0	55.3	*145*	0.0	0.0	0.0	*224*	0.0	0.0	0.0	*303*	0.0	0.0	66.7
67	0.0	0.0	5.6	*146*	0.0	0.0	0.0	*225*	0.0	0.0	0.0	*304*	0.0	0.0	4.9
68	4.2	6.9	12.5	*147*	0.0	0.0	0.0	*226*	0.0	0.0	0.0	*305*	0.0	0.0	0.0
69	0.0	0.0	5.1	*148*	0.0	0.0	0.0	*227*	0.0	0.0	0.0	*306*	0.0	0.0	0.0
70	38.8	69.4	89.8	*149*	0.0	0.0	0.0	*228*	0.0	0.0	0.0	*307*	0.0	6.5	26.1
71	23.8	69.0	100	*150*	48.6	64.3	75.7	*229*	0.0	0.0	0.0	*308*	12.0	22.0	64.0
72	67.7	80.6	90.3	*151*	100	100	100	*230*	0.0	0.0	0.0	*309*	0.0	0.0	1.5
73	75.0	100	100	*152*	0.0	0.0	0.0	*231*	0.0	0.0	0.0	*310*	0.0	0.0	2.0
74	0.0	0.0	0.0	*153*	0.0	1.2	3.7	*232*	0.0	0.0	0.0	*311*	0.0	0.0	0.0
75	100	100	100	*154*	0.0	0.0	0.0	*233*	0.0	0.0	0.0	*312*	0.0	0.0	0.0
76	16.0	60.0	72.0	*155*	0.0	0.0	0.0	*234*	0.0	0.0	0.0	*313*	0.0	0.0	0.0
77	0.0	0.0	0.0	*156*	0.0	0.0	0.0	*235*	0.0	0.0	0.0	*314*	0.0	0.0	13.3
78	8.7	43.5	43.5	*157*	0.0	0.0	0.0	*236*	0.0	0.0	0.0	*315*	14.5	16.4	23.6
79	71.4	85.7	97.1	*158*	0.0	0.0	0.0	*237*	0.0	0.0	0.0				

Acapulco

Table E.4 shows the impact of each one of the scenarios on the available shelters for the area, with a low level of impact overall.

Table E.4. Analysis of available shelters for the three scenarios in Acapulco

ID	0.5 meters	1.5 meters	2.5 meters	ID	0.5 meters	1.5 meters	2.5 meters	ID	0.5 meters	1.5 meters	2.5 meters
1	1	1	1	36	1	1	1	70	1	1	1
2	1	1	1	37	1	1	1	71	1	1	1
3	1	1	1	38	1	1	1	72	1	1	1
4	1	1	1	39	1	1	1	73	1	1	1
5	1	1	1	40	1	1	1	74	1	1	1
6	1	1	1	41	1	1	1	75	0	0	0
7	1	1	1	42	1	1	1	76	1	0	0
8	1	1	1	43	1	1	1	77	1	1	1
9	1	1	1	44	1	1	1	78	1	1	1
10	1	1	1	45	1	1	1	79	1	1	1
11	1	1	1	46	1	1	1	80	1	1	1
12	1	1	1	47	1	1	1	81	1	1	1
13	1	1	1	48	1	1	1	82	1	1	1
14	1	1	1	49	1	1	1	83	1	1	1
15	1	1	1	50	1	1	1	84	1	1	1
16	1	1	1	51	1	1	1	85	1	1	1
17	1	1	1	52	1	1	1	86	1	1	1
18	1	1	1	53	1	1	1	87	1	1	1
19	1	1	1	54	1	1	1	88	1	1	1
20	1	1	1	55	1	1	1	89	1	1	1
21	1	1	1	56	1	1	1	90	1	1	1
22	1	1	1	57	1	1	1	91	1	1	1

23	1	1	1	58	1	1	1	92	1	1	1
24	1	1	1	59	1	1	1	93	1	1	1
25	1	1	1	60	1	1	1	94	1	1	1
26	1	1	1	61	1	1	1	95	1	1	1
27	1	1	1	62	1	1	1	96	1	1	1
28	1	1	1	63	1	1	1	97	1	1	1
29	1	1	1	64	1	1	1	98	1	1	1
30	1	1	1	65	1	1	1	99	1	1	1
31	1	1	1	66	1	0	0	100	1	1	1
32	1	1	1	67	1	1	1	101	1	1	1
33	1	1	1	68	1	1	1	102	1	1	1
34	1	1	1	69	1	1	1	103	1	1	1
35	0	0	0								

On the other hand, TableE.5 includes the analysis of the distribution centres under the three scenarios, with a low level of damage overall.

Table E.5. Analysis of candidate DCs for the three scenarios in Acapulco

ID	0.5 meters	1.5 meters	2.5 meters	ID	0.5 meters	1.5 meters	2.5 meters	ID	0.5 meters	1.5 meters	2.5 meters
1	1	1	1	6	0	0	0	11	1	1	1
2	1	1	0	7	0	0	0	12	1	1	1
3	1	1	0	8	1	1	1	13	1	1	1
4	1	1	1	9	1	1	1	14	1	1	1
5	1	1	1	10	1	1	1				

Moving to the analysis of the areas affected by the flood, the level of damaged caused by each one of the scenarios can be observed on Table E.6. The damage was estimated as follows: $Damage = \frac{A_i - A_f}{A_i} * 100\%$; being A_i the initial area without the flood and A_f the final dry area after the flood. As can be seen, the damage of the areas ranges from untouched areas to zones completely covered by the flood.

Table E.6. Damage to the AGEBS for the three scenarios in Acapulco

AGEB	0.5 meters	1.5 meters	2.5 meters	AGEB	0.5 meters	1.5 meters	2.5 meters	AGEB	0.5 meters	1.5 meters	2.5 meters
1	54.05	61.43	73.22	161	0.00	0.00	0.00	320	0.00	0.00	0.00
2	70.02	84.52	92.14	162	0.00	0.00	0.00	321	0.00	0.00	0.00
3	81.58	86.84	94.74	163	0.00	0.00	0.00	322	0.00	0.00	0.00
4	96.32	99.63	99.63	164	0.00	0.00	0.00	323	0.00	0.00	0.00
5	53.29	66.09	76.12	165	0.00	0.00	0.00	324	0.00	0.00	0.00
6	99.44	99.81	100	166	0.00	0.00	0.00	325	0.00	0.00	0.00
7	84.77	92.89	97.46	167	0.00	0.00	0.00	326	0.00	0.00	0.00
8	91.77	95.57	97.47	168	0.00	0.00	0.00	327	0.00	0.00	0.00
9	90.30	96.27	98.26	169	13.17	17.96	22.16	328	0.00	0.00	0.00
10	69.57	84.06	94.20	170	0.00	0.00	0.00	329	0.00	0.00	0.00
11	94.12	100	100	171	0.00	0.00	0.00	330	0.00	0.00	0.00
12	93.33	100	100	172	0.00	0.00	0.00	331	0.00	0.00	0.00
13	11.32	11.32	18.87	173	9.23	12.31	13.85	332	0.00	0.00	0.00
14	0.00	0.00	0.00	174	0.00	0.00	0.00	333	0.00	0.00	0.00
15	0.00	0.00	0.00	175	0.00	0.00	0.00	334	100	100	100
16	0.00	0.00	0.00	176	0.00	0.00	0.00	335	0.00	0.00	0.00
17	0.00	0.00	0.00	177	0.00	0.00	0.00	336	0.00	0.00	0.00
18	10.89	14.31	16.02	178	0.00	0.00	0.00	337	0.00	0.00	0.00
19	26.37	37.62	50.48	179	0.00	0.00	0.00	338	0.00	0.00	0.00
20	1.30	3.90	6.49	180	0.00	0.00	0.00	339	0.00	0.00	0.00
21	0.00	0.00	0.00	181	0.00	0.00	0.00	340	0.00	0.00	0.00

22	48.66	60.27	75.45	182	0.00	0.00	0.00	341	0.00	0.00	0.00
23	0.00	0.00	0.00	183	0.00	0.00	0.00	342	0.00	0.00	0.00
24	0.00	0.00	0.00	184	44.00	60.00	72.00	343	0.00	0.00	0.00
25	0.00	0.00	0.00	185	65.63	76.97	86.65	344	0.00	0.00	0.00
26	0.00	0.00	0.00	186	0.00	0.00	0.00	345	0.00	0.00	0.00
27	19.48	20.78	20.78	187	0.00	0.00	0.00	346	0.00	0.00	0.00
28	5.36	5.36	7.14	188	23.97	28.93	43.80	347	0.00	0.00	0.00
29	0.00	0.00	0.00	189	0.00	0.00	0.60	348	0.00	0.00	0.00
30	0.00	0.00	0.00	190	0.00	0.00	6.56	349	0.00	0.00	0.00
31	0.00	0.00	5.26	191	8.82	10.00	11.76	350	0.00	0.00	0.00
32	0.00	0.00	0.00	192	1.74	2.33	3.49	351	0.00	0.00	0.00
33	12.50	12.50	12.50	193	0.00	0.00	0.00	352	0.00	0.00	0.00
34	0.00	0.00	0.00	194	6.52	13.04	15.22	353	0.00	0.00	0.00
35	0.00	0.00	0.00	195	0.00	2.56	2.56	354	0.00	0.00	0.00
36	3.70	14.81	25.93	196	0.00	0.00	3.57	355	0.00	0.00	0.00
37	0.00	0.00	0.00	197	0.00	0.00	0.00	356	0.00	0.00	0.00
38	0.00	0.00	0.00	198	0.00	0.00	0.00	357	0.00	0.00	0.00
39	100	100	100	199	3.16	3.16	4.74	358	0.00	0.00	0.00
40	0.00	0.00	0.00	200	85.71	90.48	90.48	359	0.00	0.00	0.00
41	0.00	0.00	0.00	201	0.00	0.00	0.00	360	0.00	0.00	0.00
42	0.00	0.00	0.00	202	0.00	0.00	0.00	361	0.00	0.00	0.00
43	0.00	0.00	0.00	203	0.00	0.00	0.00	362	0.00	0.00	0.00
44	0.00	0.00	4.17	204	0.00	0.00	0.00	363	0.00	0.00	0.00
45	0.00	0.00	0.00	205	0.00	0.00	0.00	364	0.00	0.00	0.00
46	0.00	0.00	0.00	206	0.00	0.00	0.00	365	0.00	0.00	0.00
47	0.00	0.00	0.00	207	0.00	0.00	0.00	366	0.00	0.00	0.00
48	0.00	0.00	0.00	208	0.00	0.00	0.00	367	0.00	0.00	0.00

49	0.00	0.00	0.00	209	0.00	0.00	0.00	368	0.00	0.00	0.00
50	0.00	0.00	0.00	210	0.00	0.00	0.00	369	0.00	0.00	0.00
51	100	100	100	211	0.00	0.00	0.00	370	0.00	0.00	0.00
52	0.00	0.00	0.00	212	2.13	4.26	6.38	371	0.00	0.00	0.00
53	0.00	0.00	0.00	213	0.00	0.00	0.00	372	0.00	0.00	0.00
54	0.00	0.00	0.00	214	0.00	0.00	0.00	373	0.00	0.00	0.00
55	100	100	100	215	0.00	0.00	0.00	374	0.00	0.00	0.00
56	0.00	0.00	0.00	216	0.00	0.00	0.00	375	0.00	0.00	0.00
57	100	100	100	217	0.00	0.00	0.00	376	0.00	0.00	0.00
58	0.00	0.00	0.00	218	0.00	0.00	0.00	377	0.00	0.00	0.00
59	2.03	3.38	3.38	219	0.00	0.00	0.00	378	100	100	100
60	2.75	2.75	4.59	220	0.00	0.00	0.00	379	69.57	82.61	86.96
61	4.21	5.26	6.32	221	0.00	0.00	0.00	380	0.00	1.75	4.39
62	8.39	9.79	10.49	222	0.00	0.00	0.00	381	0.00	0.00	4.88
63	0.00	0.00	0.00	223	0.00	0.00	0.00	382	0.00	4.92	21.31
64	0.00	0.00	0.00	224	0.00	0.00	0.00	383	70.19	82.69	91.35
65	0.00	0.00	0.00	225	0.00	0.00	0.00	384	34.69	59.18	85.71
66	0.00	0.00	0.00	226	0.00	0.00	0.00	385	37.04	51.85	74.07
67	0.00	0.00	0.00	227	0.00	0.00	0.00	386	33.33	41.67	55.56
68	0.00	0.00	0.00	228	0.00	0.00	0.00	387	67.65	76.47	88.24
69	0.00	0.00	0.00	229	0.00	0.00	0.00	388	15.79	52.63	78.95
70	0.00	0.00	0.00	230	0.00	0.00	0.00	389	10.00	30.00	60.00
71	0.00	0.00	0.00	231	0.00	0.00	0.00	390	0.00	0.00	0.00
72	0.00	0.00	0.00	232	0.00	0.00	0.00	391	0.00	12.50	25.00
73	0.00	0.00	0.00	233	0.00	0.00	0.00	392	0.00	0.00	0.00
74	0.00	0.00	0.00	234	0.00	0.00	0.00	393	0.00	9.09	9.09
75	0.00	0.00	0.00	235	0.00	0.00	0.00	394	0.00	0.00	0.00

76	0.00	0.00	0.00	236	0.00	0.00	0.00	395	0.00	0.00	0.00
77	0.00	2.94	5.88	237	0.00	0.00	0.00	396	33.33	50.00	66.67
78	4.76	4.76	4.76	238	0.00	0.00	0.00	397	0.00	20.00	60.00
79	0.00	6.25	6.25	239	0.00	0.00	0.00	398	40.91	45.45	54.55
80	0.00	0.00	0.00	240	0.00	0.00	0.00	399	22.22	33.33	55.56
81	0.00	0.00	0.00	241	0.00	0.00	0.00	400	18.18	18.18	27.27
82	0.00	0.00	0.00	242	0.00	0.00	0.00	401	23.08	30.77	53.85
83	0.00	0.00	0.00	243	0.00	0.00	0.00	402	18.52	29.63	37.04
84	0.00	0.00	0.00	244	100	100	100	403	33.33	48.15	59.26
85	0.00	0.00	0.00	245	0.00	0.00	0.00	404	71.43	85.71	85.71
86	0.00	0.00	0.00	246	0.00	0.00	0.00	405	0.00	0.00	0.00
87	0.00	0.00	0.00	247	0.00	0.00	0.00	406	0.00	3.57	7.14
88	0.00	0.00	0.00	248	0.00	0.00	0.00	407	0.00	0.00	5.00
89	0.00	0.00	0.00	249	0.00	0.00	0.00	408	0.00	0.00	0.00
90	0.00	0.00	0.00	250	6.35	7.14	7.14	409	0.00	0.00	0.00
91	7.41	7.41	11.11	251	14.16	15.04	19.47	410	0.00	0.00	0.00
92	7.14	7.14	7.14	252	0.00	0.00	1.28	411	0.00	0.00	0.00
93	0.00	0.00	0.00	253	0.00	0.00	0.00	412	0.00	0.00	0.00
94	0.00	0.00	0.00	254	0.00	0.00	0.00	413	0.00	0.00	0.00
95	0.00	0.00	0.00	255	0.00	0.00	0.00	414	0.00	0.00	0.00
96	0.00	0.00	0.00	256	0.00	0.00	0.00	415	0.00	0.00	0.00
97	0.00	0.00	0.00	257	0.00	0.00	0.00	416	0.00	0.00	0.00
98	0.00	0.00	0.00	258	0.00	0.00	0.00	417	0.00	0.00	0.00
99	0.00	0.00	0.00	259	0.00	0.00	0.00	418	100	100	100
100	0.00	0.00	0.00	260	0.00	0.00	0.00	419	0.00	0.00	0.00
101	0.00	0.00	0.00	261	0.00	0.00	0.00	420	0.00	0.00	0.00
102	0.00	0.00	0.00	262	0.00	0.00	0.00	421	0.00	0.00	0.00

103	0.00	0.00	0.00	263	0.00	0.00	0.00	422	0.00	0.00	0.00
104	0.00	0.00	0.00	264	0.00	0.00	0.00	423	0.00	0.00	0.00
105	0.00	0.00	0.00	265	0.00	0.00	0.00	424	0.00	0.00	0.00
106	0.00	0.00	0.00	266	0.00	0.00	0.00	425	0.00	0.00	0.00
107	0.00	0.00	0.00	267	0.00	0.00	0.00	426	0.00	0.00	0.00
108	0.00	0.00	0.00	268	0.00	0.00	0.00	427	0.00	0.00	0.00
109	0.00	0.00	0.00	269	0.00	0.00	0.00	428	0.00	0.00	0.00
110	0.00	0.00	0.00	270	0.00	0.00	0.00	429	0.00	0.00	0.00
111	18.52	20.37	33.33	271	0.00	0.00	0.00	430	0.00	0.00	0.00
112	0.00	0.00	0.00	272	0.00	0.00	0.00	431	0.00	0.00	0.00
113	0.00	0.00	0.00	273	0.00	0.00	0.00	432	0.00	0.00	0.00
114	0.00	0.00	0.00	274	0.00	0.00	0.00	433	0.00	0.00	0.00
115	0.00	0.00	0.00	275	0.00	0.00	0.00	434	100	100	100
116	12.50	23.08	37.50	276	0.00	0.00	0.00	435	0.00	0.00	0.00
117	0.00	0.00	5.56	277	0.00	0.00	0.00	436	0.00	0.00	0.00
118	4.76	9.52	23.81	278	0.00	0.00	0.00	437	0.00	0.00	0.00
119	0.00	0.00	0.00	279	0.00	0.00	0.00	438	0.00	0.00	0.00
120	0.00	0.00	0.00	280	0.00	0.00	0.00	439	0.00	0.00	0.00
121	0.00	0.00	0.00	281	0.00	0.00	0.00	440	0.00	0.00	0.00
122	0.00	0.00	0.00	282	0.00	0.00	0.00	441	0.00	0.00	0.00
123	0.00	0.00	0.00	283	0.00	0.00	0.00	442	0.00	0.00	0.00
124	0.00	5.00	5.00	284	0.00	0.00	0.00	443	0.00	0.00	0.00
125	0.00	0.00	0.00	285	0.00	0.00	0.00	444	0.00	0.00	0.00
126	0.00	0.00	0.00	286	0.00	0.00	0.00	445	0.00	0.00	0.00
127	0.00	0.00	0.00	287	0.00	0.00	0.00	446	0.00	0.00	0.00
128	0.00	0.00	0.00	288	0.00	0.00	0.00	447	0.00	0.00	0.00
129	0.00	0.00	0.00	289	0.00	0.00	0.00	448	0.00	0.00	0.00

130	0.00	0.00	0.00	290	0.00	0.00	0.00	449	0.00	0.00	0.00
131	0.00	0.00	0.00	291	0.00	0.00	0.00	450	0.00	0.00	0.00
132	0.00	0.00	0.00	292	100	100	100	451	0.00	0.00	0.00
133	0.00	0.00	0.00	293	100	100	100	452	0.00	0.00	0.00
134	0.00	0.00	0.00	294	0.00	0.00	0.00	453	0.00	0.00	0.00
135	0.00	0.00	0.00	295	100	100	100	454	0.00	0.00	0.00
136	0.00	0.00	0.00	296	0.00	0.00	0.00	455	0.00	0.00	0.00
137	0.00	0.00	0.00	297	100	100	100	456	0.00	0.00	0.00
138	100	100	100	298	0.00	0.00	0.00	457	0.00	0.00	0.00
139	0.00	0.00	0.00	299	0.00	0.00	0.00	458	0.00	0.00	0.00
140	0.00	1.12	1.12	300	0.00	0.00	0.00	459	0.00	0.00	0.00
141	0.00	0.00	1.49	301	0.00	0.00	0.00	460	0.00	0.00	0.00
142	62.50	79.17	91.67	302	0.00	0.00	0.00	461	100	100	100
143	84.21	100	100	303	0.00	0.00	0.00	462	0.00	0.00	0.00
144	100	100	100	304	0.00	0.00	0.00	463	0.00	0.00	0.00
145	0.00	0.00	0.00	305	0.00	0.00	0.00	464	0.00	0.00	0.00
146	0.00	0.00	0.00	306	0.00	0.00	0.00	465	0.00	0.00	0.00
147	0.00	0.00	0.00	307	0.00	0.00	0.00	466	0.00	0.00	0.00
148	0.00	0.00	0.00	308	100	100	100	467	0.00	0.00	0.00
149	0.00	0.00	0.00	309	0.00	0.00	0.00	468	100	100	100
150	0.00	0.00	0.00	310	0.00	0.00	0.00	469	0.00	0.00	0.00
151	0.00	0.00	0.00	311	0.00	0.00	0.00	470	1.43	1.43	1.43
152	0.00	0.00	0.00	312	0.00	0.00	0.00	471	60.78	68.63	73.53
153	0.00	0.00	0.00	313	0.00	0.00	0.00	472	25.00	33.33	50.00
154	0.00	0.00	0.00	314	0.00	0.00	0.00	473	0.00	0.00	0.00
155	0.00	0.00	0.00	315	0.00	0.00	0.00	474	100	100	100
156	0.00	0.00	0.00	316	0.00	0.00	0.00	475	0.00	0.00	0.00

157	0.00	0.00	0.00	317	0.00	0.00	0.00	476	0.00	0.00	0.00
158	0.00	0.00	0.00	318	0.00	0.00	0.00	477	0.00	0.00	0.00
159	0.00	0.00	0.00	319	0.00	0.00	0.00	478	0.00	0.00	0.00
160	0.00	0.00	0.00								

Villahermosa

Table E.7 includes the analysis performed under three scenarios to available facilities in the region of Villahermosa, with a value of 1 for facilities surviving the flood and values of 0 otherwise.

Table E.7. Candidate shelters for the three scenarios in Villahermosa

ID	1 meter	2 meters	4 meters	ID	1 meter	2 meters	4 meters	ID	1 meter	2 meters	4 meters	ID	1 meter	2 meters	4 meters
1	1	1	1	112	1	1	1	223	1	1	1	334	1	1	1
2	1	1	1	113	1	1	1	224	1	1	1	335	1	1	1
3	1	1	1	114	1	1	1	225	1	1	1	336	1	1	1
4	1	1	1	115	1	1	1	226	1	1	1	337	1	1	1
5	1	1	1	116	1	1	1	227	1	1	1	338	1	1	1
6	1	1	1	117	1	1	1	228	1	1	1	339	0	0	0
7	1	1	1	118	1	1	1	229	1	1	1	340	1	1	1
8	1	1	1	119	1	1	1	230	1	1	1	341	1	1	1
9	1	1	1	120	1	1	1	231	1	1	1	342	1	1	1
10	1	1	1	121	1	1	1	232	1	1	1	343	1	1	1
11	1	1	1	122	1	1	1	233	1	1	1	344	1	1	1
12	1	1	1	123	1	1	1	234	0	0	0	345	1	1	1
13	1	1	1	124	1	1	1	235	0	0	0	346	1	1	1
14	1	1	1	125	1	1	0	236	1	1	1	347	1	1	0
15	0	0	0	126	1	1	0	237	1	1	1	348	1	1	0

16	1	1	1	127	1	1	0	238	0	0	0	349	1	1	1
17	1	1	1	128	1	1	1	239	1	1	1	350	1	1	1
18	1	1	0	129	1	1	1	240	1	1	1	351	1	1	1
19	1	1	1	130	1	1	0	241	1	1	1	352	1	1	0
20	1	1	1	131	1	0	0	242	1	1	1	353	1	1	1
21	1	1	1	132	1	1	0	243	1	1	1	354	0	0	0
22	1	1	1	133	0	0	0	244	1	1	1	355	1	1	0
23	1	1	1	134	1	1	1	245	1	1	1	356	1	0	0
24	1	1	1	135	1	1	1	246	1	1	1	357	0	0	0
25	1	1	1	136	1	1	1	247	1	1	0	358	1	0	0
26	1	1	0	137	1	1	1	248	1	1	1	359	0	0	0
27	1	1	1	138	1	1	1	249	1	1	1	360	0	0	0
28	1	0	0	139	1	1	1	250	1	1	1	361	0	0	0
29	0	0	0	140	1	1	1	251	1	1	1	362	1	0	0
30	1	1	1	141	1	1	1	252	1	1	1	363	1	1	1
31	1	1	1	142	1	1	1	253	1	1	1	364	1	1	1
32	1	1	0	143	0	0	0	254	1	1	1	365	0	0	0
33	0	0	0	144	1	0	0	255	1	1	1	366	1	1	1
34	1	1	1	145	1	1	1	256	1	1	1	367	1	1	0
35	1	1	1	146	1	1	1	257	1	1	1	368	1	1	1
36	1	1	1	147	1	1	1	258	1	1	1	369	1	1	1
37	1	1	1	148	1	1	0	259	1	1	1	370	1	1	0
38	1	1	1	149	1	1	1	260	1	1	1	371	0	0	0
39	1	1	1	150	1	1	0	261	1	0	0	372	1	1	1
40	0	0	0	151	1	0	0	262	1	0	0	373	1	1	1
41	0	0	0	152	1	1	1	263	0	0	0	374	1	1	0
42	1	1	0	153	1	1	0	264	1	1	0	375	1	1	0

43	1	1	1	154	0	0	0	265	1	1	0	376	1	1	1
44	0	0	0	155	1	1	0	266	1	1	0	377	1	1	1
45	1	1	1	156	0	0	0	267	1	1	0	378	1	1	1
46	1	1	1	157	1	1	0	268	0	0	0	379	0	0	0
47	1	1	1	158	0	0	0	269	1	1	0	380	1	1	1
48	1	1	1	159	1	0	0	270	1	1	0	381	1	1	1
49	1	1	0	160	1	0	0	271	0	0	0	382	1	1	1
50	1	1	1	161	1	1	0	272	1	1	0	383	0	0	0
51	0	0	0	162	1	1	1	273	1	1	1	384	0	0	0
52	1	1	1	163	0	0	0	274	1	1	0	385	0	0	0
53	1	1	1	164	1	1	0	275	1	1	1	386	1	1	0
54	1	1	1	165	1	1	0	276	1	1	1	387	1	0	0
55	1	1	1	166	1	0	0	277	1	1	1	388	0	0	0
56	1	1	1	167	1	1	1	278	1	1	1	389	1	1	1
57	1	1	1	168	1	1	1	279	1	1	1	390	1	1	1
58	0	0	0	169	1	1	1	280	1	1	1	391	1	1	1
59	1	1	1	170	1	1	1	281	1	1	1	392	1	1	1
60	0	0	0	171	1	1	1	282	1	1	1	393	1	1	0
61	1	1	0	172	1	1	1	283	1	1	1	394	1	1	0
62	1	1	1	173	0	0	0	284	0	0	0	395	0	0	0
63	1	1	1	174	0	0	0	285	1	1	1	396	0	0	0
64	1	1	1	175	0	0	0	286	0	0	0	397	1	0	0
65	1	1	1	176	0	0	0	287	1	1	1	398	0	0	0
66	1	1	1	177	0	0	0	288	1	1	1	399	0	0	0
67	0	0	0	178	1	0	0	289	1	1	1	400	1	0	0
68	1	1	1	179	0	0	0	290	1	1	1	401	1	1	0
69	1	1	1	180	1	1	0	291	1	1	1	402	1	1	1

70	1	1	0	181	1	0	0	292	1	1	1	403	0	0	0
71	1	1	1	182	0	0	0	293	1	1	1	404	1	1	1
72	0	0	0	183	1	1	0	294	1	1	1	405	1	1	1
73	1	1	1	184	0	0	0	295	0	0	0	406	1	1	1
74	1	1	0	185	0	0	0	296	1	1	0	407	1	0	0
75	0	0	0	186	0	0	0	297	1	0	0	408	1	1	1
76	1	1	1	187	1	1	0	298	1	1	0	409	1	1	1
77	1	1	1	188	1	1	1	299	1	0	0	410	1	1	1
78	0	0	0	189	1	1	0	300	1	1	1	411	1	1	1
79	0	0	0	190	1	1	1	301	1	1	1	412	1	1	1
80	0	0	0	191	1	1	1	302	1	1	1	413	1	1	1
81	1	1	1	192	1	1	1	303	1	1	1	414	1	1	0
82	1	1	1	193	1	1	0	304	1	1	1	415	1	1	1
83	1	1	1	194	1	1	1	305	1	1	1	416	1	0	0
84	1	1	1	195	1	1	1	306	1	0	0	417	1	1	0
85	1	1	1	196	1	1	1	307	1	1	1	418	1	1	0
86	1	1	1	197	1	0	0	308	1	1	1	419	1	1	1
87	1	1	1	198	1	1	1	309	0	0	0	420	1	1	0
88	1	1	1	199	1	1	1	310	1	0	0	421	1	1	1
89	1	1	0	200	1	1	1	311	1	1	1	422	1	1	1
90	0	0	0	201	1	1	1	312	1	1	1	423	0	0	0
91	1	1	1	202	1	1	1	313	1	1	1	424	1	1	1
92	1	1	1	203	1	1	1	314	1	1	1	425	1	1	0
93	1	1	1	204	0	0	0	315	1	1	1	426	1	1	1
94	1	1	1	205	1	1	1	316	1	1	1	427	1	1	1
95	1	1	1	206	0	0	0	317	1	1	1	428	1	1	1
96	1	1	1	207	1	1	1	318	1	1	1	429	1	1	1

97	1	1	1	208	1	1	1	319	1	1	1	430	0	0	0
98	1	1	1	209	0	0	0	320	1	1	1	431	1	1	1
99	1	1	1	210	1	1	1	321	1	1	1	432	1	1	0
100	1	1	0	211	1	1	1	322	1	1	1	433	0	0	0
101	0	0	0	212	1	1	1	323	1	1	1	434	1	0	0
102	1	1	1	213	1	1	1	324	1	1	1	435	1	0	0
103	0	0	0	214	1	1	1	325	1	1	1	436	0	0	0
104	1	0	0	215	1	1	1	326	1	1	1	437	0	0	0
105	0	0	0	216	1	1	1	327	1	1	1	438	1	1	1
106	0	0	0	217	1	1	1	328	1	1	1	439	1	1	1
107	0	0	0	218	0	0	0	329	1	1	1	440	1	0	0
108	1	1	1	219	1	1	1	330	1	1	1	441	0	0	0
109	1	1	1	220	1	1	1	331	1	1	1	442	1	1	0
110	1	1	1	221	1	1	1	332	1	1	1	443	1	1	1
111	1	1	1	222	1	1	1	333	1	1	1				

Continuing with the analysis of facilities, Table E.8 displays the impact of the floods on the three scenarios for the list of distribution centres.

Table E.8. Candidate distribution centres for the three scenarios in Villahermosa

DC	1 m	2 m	4 m	DC	1 m	2 m	4 m	DC	1 m	2 m	4 m
A	1	0	0	*I*	1	1	1	*P*	1	1	1
B	1	1	1	*J*	1	1	1	*Q*	1	1	1
C	1	1	1	*K*	1	1	1	*R*	1	1	0
D	1	1	1	*L*	1	1	1	*S*	1	1	1
E	1	1	0	*M*	1	1	1	*T*	1	1	1
F	1	1	1	*N*	1	1	1	*U*	1	1	1
G	1	1	1	*O*	1	1	1	*V*	1	0	0
H	1	1	1								

On the other hand, the damage to the demand areas for the different conditions was also checked, and it can be seen on Table E.9. This level of damage was estimated as follows: $Damage = \frac{A_i - A_f}{A_i} * 100\%$; being A_i the initial area without the flood and A_f the final dry area after the flood.

Table E.9. Damage to the AGEBS for the three scenarios in Villahermosa

AGEB	**1 m**	**2 m**	**4 m**	**AGEB**	**1 m**	**2 m**	**4 m**	**AGEB**	**1 m**	**2 m**	**4 m**
1	3.39	8.59	33.37	50	2.84	5.68	22.73	99	30.04	44.84	65.92
2	1.55	8.14	22.48	51	1.23	7.41	24.69	100	3.33	4.44	7.78
3	9.78	34.78	55.43	52	4.55	13.64	36.36	101	0	4.35	21.74
4	42.38	45.70	54.30	53	11.02	20.47	44.09	102	17.02	34.04	70.21
5	2.97	3.96	7.92	54	35.65	53.04	86.96	103	1.98	2.97	8.91
6	4.76	7.62	21.90	55	22.22	44.44	88.89	104	3.77	3.77	41.51
7	28.24	40.35	75.79	56	4.86	15.28	53.47	105	44.16	54.55	63.64
8	0	0	0	57	0	2.63	36.84	106	14.29	28.57	75.00
9	22.96	37.78	69.63	58	0	50	100	107	0	26.32	68.42
10	5.88	8.24	11.76	59	8.22	16.44	71.23	108	33.33	75.00	95.83
11	26.79	42.86	69.39	60	0	0	100	109	28.00	48.50	80
12	0	0	0	61	0	50	100	110	29.23	49.23	83.08
13	0	0	3.16	62	0	100	100	111	57.35	82.35	95.59
14	2.91	11.65	54.37	63	0	0	0	112	26.32	31.58	57.89
15	6.95	18.53	57.92	64	0	0	0	113	71.72	86.68	97.54
16	35.95	50.33	66.01	65	0	0	0	114	0	11.63	41.86
17	27.89	36.05	53.06	66	0	0	0	115	0	9.68	16.13
18	0	21.43	64.29	67	0	0	0	116	0	0	3.70
19	3.33	16.67	66.67	68	0	0	5.00	117	61.15	73.89	93.95
20	31.10	40.48	58.71	69	0	0	0	118	35.71	47.62	85.71
21	11.59	23.19	62.80	70	0	0	0	119	48.28	65.52	86.21
22	0	2.70	29.73	71	0	0	0	120	67.62	83.81	98.10

23	0	0	2.02	72	0	0	0	121	48.48	63.64	100
24	10.53	21.05	84.21	73	0	0	0	122	38.00	52.00	80
25	0	0	5.45	74	0	0	0	123	50.94	64.15	92.45
26	0	0	2.17	75	1.72	1.72	10.34	124	61.11	100	100
27	3.85	3.85	30.77	76	6.73	16.35	39.42	125	55.77	75.00	97.12
28	6.25	17.97	64.84	77	8.70	14.49	56.52	126	66.67	91.67	100
29	0	4.46	29.30	78	1.35	5.41	16.22	127	4.35	4.35	21.74
30	44.64	64.29	98.21	79	0	0	3.33	128	12.12	27.27	90.91
31	56.10	70.73	97.56	80	4.17	4.17	12.50	129	46.43	64.29	92.86
32	0	0	33.33	81	6.35	20.63	69.84	130	96.30	100	100
33	26.88	41.94	70.97	82	31.71	53.66	80.49	131	90.32	96.77	100
34	36.57	47.76	70.15	83	33.33	33.33	83.33	132	37.50	50	90.63
35	12.75	21.57	52.94	84	100	100	100	133	61.11	74.07	95.37
36	4.76	7.14	57.14	85	100	100	100	134	0	6.06	51.52
37	16.00	44.00	88.00	86	24.56	42.98	70.18	135	52.17	60.87	91.30
38	26.67	46.67	93.33	87	53.33	66.67	73.33	136	71.20	79.06	92.15
39	17.65	41.18	94.12	88	100	100	100	137	7.50	23.75	58.75
40	8.47	16.95	52.20	89	100	100	100	138	8.33	8.33	50
41	25.00	25.00	75.00	90	0	66.67	66.67	139	22.73	45.45	86.36
42	0	0	0	91	2.35	5.88	23.53	140	77.14	91.43	100
43	0	0	1.25	92	0	0	0	141	61.11	80.56	100
44	0	0	0	93	0	0	0.86	142	63.64	87.88	100
45	2.70	2.70	8.11	94	0	0	0	143	98.98	98.98	100
46	0	0	0	95	0	0	2.50	144	75.00	83.82	97.06
47	0	5.41	16.22	96	12.28	22.81	78.95	145	7.69	30.77	84.62
48	1.49	5.97	19.40	97	0	0	16.67	146	0	28.57	100
49	6.92	12.31	25.38	98	0	0	28.33	147	100	100	100

Appendix F. Relief products delivered in Mexico

Preparedness

For the case studies at hand, we are concerned with supplies directly related to the welfare and survival of people sheltered. The relief items that can be charged to FONDEN are properly regulated and included in the Appendix IV of the "Acuerdo que establece los lineamientos del Fondo para la Atención de emergencias". Therefore, in Table F.1 you can see the list of the 42 items comprised in Appendix IV, mentioning that from that list only the food pantries are included in the preparedness model. The reason for governmental agencies not to preposition items different to the pantries is related to budgetary purposes and the nature of immediate response.

Table F.1. Relief items delivered in Mexico

ID	Name	Unit	People served per unit	ID	Name	Unit	People served per unit
1	Food pantry	Box	4	22	Machete	Piece	Several
2	Laminate type "A"	Sheet	1	23	Hoe	Piece	Several
3	Laminate type "B"	Sheet	Several	24	Axe	Piece	Several
4	Blanket type "A" Cold weather	Piece	1	25	Sprayer	Piece	Several
5	Blanket type "B" Warm weather	Piece	1	26	Hammer	Piece	Several
6	Mat	Piece	1	27	Cleaning kit	Box	4
7	Raincoat	Piece	1	28	Personal kit	Box	4
8	Gloves	Pair	1	29	Feminine Hygiene towels	Piece	1
9	Boots	Pair	1	30	Diaper 1	Piece	1
10	Mask "A"	Piece	1	31	Diaper 2	Piece	1
11	Mask "B"	Piece	1	32	Diaper 3	Piece	1
12	Foam rolls	Roll	1	33	Diaper 4	Piece	1
13	Bag of sand	Piece	Several	34	Diaper 5	Piece	1
14	Flashlight	Piece	1	35	Adult diaper	Piece	1
15	Mallet	Piece	Several	36	Baby bathtub	Piece	Several
16	Small bar	Piece	Several	37	Body bag	Piece	1
17	Chisel	Piece	Several	38	Neoprene gloves 20 thousandth	Pair	1
18	Wheelbarrow	Piece	Several	39	Neoprene gloves 40 thousandth	Pair	1
19	Shovel	Piece	Several	40	Laminate type "C"	Sheet	Several
20	Pickax	Piece	Several	41	Water container	Piece	Several
21	Helmet	Piece	Several	42	Mask "C"	Piece	1

Obtaining the prices was complicated given the control of governmental authorities and the fear to provide information that can aid competitors from governmental suppliers in future request for bids. The products included in the food pantry were obtained from the rules for FONDEN (http://www.proteccioncivil.gob.mx/work/models/ProteccionCivil/Resource/21/10/images/LINEAMIENTOS%20DOF%202012%20-3jul12-.pdf) and are shown on Table F.2.

Table F.2. Products delivered on the food pantry in Mexico

Item	Quantity	Item	Quantity
Soluble coffee	Minimum 50 gr.	Tuna or sardines	Minimum 1275 gr.
Chocolate powder	Minimum 250 gr.	Instant soup	Minimum 328 gr.
Cooked beans	Minimum 1200 gr.	Jalapeno peppers	Minimum 200 gr. Minimum 400 gr.
Maize flour	One Kg.	Chilorio or cochinita pibil	Minimum 250 gr.
Milk powder	Minimum 480 gr.	Bar or cookies of oats or amaranth	Minimum 400 gr.
Pre-cooked rice	Minimum 750 gr.		

However, the products showed above were approved on 2012 and not exactly the same for the floods of Tabasco and Veracruz. Moreover, given the reluctance of authorities to share information about the items prepositioned before the flood of Acapulco there is no information if the proof products were updated or the stock was of previous products. As a result for this research a single food pantry based on the items established previous to the legislation change in 2012 was used. The legislation at that time included the articles shown in Rodríguez-Espíndola (2011) and displayed on Table F.3, with slight changes on some of the products and stating substitute products.

Table F.3. Relief items distributed in Mexico before the legislation change in 2012

Item	Substitute products
Sugar: 1 kg.	N/A
Soluble coffee: Minimum 50 gr.	N/A
Cooked beans: Minimum 1200 gr.	N/A
Maize flour: 1 kilo	N/A
Milk powder: Minimum 480 gr.	N/A
Pre-cooked rice: Minimum 750 gr.	Cereal (oats, cornflakes o puffed rice): Minimum 400 gr.
Tuna: Minimum 1360 gr.	Sardines: Minimum 1275 gr.
Cookies: 1 kilo	N/A
Instant soup: Minimum 328 gr.	N/A
Jalapeno peppers: Minimum 200 gr.	N/A
Milk-based sweets: Minimum 100 gr.	Hard candy: Minimum 100 gr.

In terms of prices, DICONSA (agency in charge of purchasing the products) stated the right to protect the prices and suppliers for at least 3 years (DICONSA, 2013a), therefore obtaining the prices for Acapulco was not possible yet. However, a revision recourse of the same request asked for the unreleased prices for the floods in Veracruz and Tabasco, and the prices were given. Therefore the prices contained in this research come from DICONSA (2013b). However, the information provided for the state of Veracruz did not contained unit of measure, deriving in inconsistencies in the information and providing reliable information only on the flood of Tabasco in 2007. On top of that, not all the prices were released by authorities even for Tabasco, and supplementary input was needed. SEGOB et al. (2008) performed an exhaustive analysis of the floods in Tabasco at 2007, therefore that information was used to supplement the governmental information and checked for consistency with the information available in Veracruz, Tabasco and Chiapas to ensure its accuracy. The results were satisfactory and the costs used for this research were determined.

Also, this research is considering a comprehensive approach by including sheltercare, healthcare and relief distribution. Under that umbrella, carrying out medical care requires medicines. According to SS (2014a), Mexican authorities consider the use of one kit of medicines per 1000 people per month (Health Ministry, personal communication 2nd September 2014) containing the items displayed on Table F.4.

Table F.4. Medicine kit used by Mexican authorities

NAME AND DESCRIPTION	UNIT	AMOUNT
ALBENDAZOL 200 mg Envase con 2 tabletas	BOX	100
ALBENDAZOL 20 mg/ml Envase 20 ml	FCC	100
ALUMINIO Y MAGNESIO 3.7 g y 4 g/100 ml Envase con 240 ml	FCC	50
AMBROXOL 300 mg/100 ml envase con 120 ml	FCC	50
AMOXICILINA 500 MG	BOX	50
AMOXICILINA 500 mg/5 ml Envase para 75 ml	FCC	50
AMPICILINA 500 MG	BOX	30
AMPICILINA 250 mg/5 ml Envase con 60 ml	FCC	30
BUTILHIOSCINA 10 mg Envase con 10 grageas	BOX	20
BUTILHIOSCINA 20 mg/ml Envase con 3 ampolletas	VIAL	20
CAPTOPRIL 25 mg Envase con 30 tabletas	BOX	40
CLIOQUINOL 20 G	BOTTLE	100
CLORAMFENICOL	DROPPER	100

CLORFENAMINA SIMPLE	BOX	20
DICLOFENACO SODICO 100 MG	BOX	20
DICLOXACILINA 250 MG	BOX	30
DIFENHIDRAMINA 60 ML	FCC	10
DOXICICLINA 100 MG	BOX	50
DOXICICLINA 100 MG	BOX	50
ERITROMICINA 250 MG	FCC	50
ERITROMICINA 500 MG	BOX	50
GLIBENCLAMIDA 5MG	BOX	40
ISOSORBIDA TABS 10 MG	BOX	10
KETOCONAZOL 200 MG	BOX	30
METAMIZOL SODICO 500 MG	BOX	20
METFORMINA 850 MG	BOX	40
METOCLOPRAMIDA 10 MG	FCC	50
METOPROLOL 100 MG	BOX	10
METRONIDAZOL TABS	BOX	30
METRONIDAZOL SUSP 120 Ml	FCC	30
MICONAZOL 20 G	BOTTLE	100
NAFAZOLINA	DROPPER	200
NAPROXENO 250 MG	BOX	40
NEOMICINA POLIMIXINA	DROPPER	100
NIFEDIPINO	BOX	10
OXIDO DE ZINC 20 G	BOTTLE	100
PARACETAMOL 500 MG	BOX	200
PARACETAMOL FCC. GOTERO 15 ML	DROPPER	150
PENICILINA BENZ COMB 1200,000 UI	BOX	100
PENICILINA PROCAINICA 400,000 UI	BOX	200
PENICILINA PROCAINICA 800,000 UI	BOX	200
RANITIDINA 150 MG	BOX	50
SALBUTAMOL 200 DOSIS	FCO	10
SALBUTAMOL 60ML	FCO	10
TRIMETOPRIM CON SULFAMETOXAZOL 80/399 TABS	BOX	50
TRIMETOPRIM CON SULFAMETOXAZOL, SUSP 120 ML CON 40/200 MG	FCO	50
ELECTROLITOS ORALES	ENVELOPE	600

Usually authorities have a centralized control over the kits and therefore they break it down according to needs (Health Ministry, personal communication 2nd September 2014). However, for the model the assumption was decided that the kit for 1000 people could be broken down as 10 kits for 100 people.

Governmental authorities did not provided information about the weight and volume of the products, therefore the values were obtained empirically. The kit was disaggregated at product level, and then based on the type of presentation (box, bottle, envelope, and dropper) a prospective measure was used as basis for the analysis. The cost of the items included in the medicine kit were disclosed by SS (2014b) excluding the cost of DICLOXACILINA 250 M, therefore the cost was obtained from SSG (2014). Moreover, SST (2014) also provided a list of items and prices, but given the relevance of the Health Ministry as overarching governmental body the information from SST (2014) information was used only for support.

Response

The response model also includes food pantries and medicine kits, but to align this work with real activities performed on the field, each one of the items included on Appendix IV of SEGOB (2012) were checked and the decision about each one of the items can be seen on Table F.5, including the reasoning behind every decision and focusing on supplies directly related to the welfare and survival of people sheltered.

Table F.5. Selection of relief products included for the response model

ID	Name	Unit	Served per unit	Inclusion in the response model	Reasoning
1	Food pantry	Box	4	Yes	Basic unit for food for four days
2	Laminate type "A"	Sheet	1	No	Mostly used for recovery activities and houses
3	Laminate type "B"	Sheet	Several	No	Mostly used for recovery activities and houses
4	Blanket type "A" Cold	Piece	1	Included	Supplied at preparedness on shelters

	weather				
5	Blanket type "B" Warm weather	Piece	1	Included	Supplied at preparedness on shelters
6	Mat	Piece	1	Included	Supplied at preparedness on shelters
7	Raincoat	Piece	1	Included	Supplied at preparedness on shelters
8	Gloves	Pair	1	No	Provided to communities for recovery
9	Boots	Pair	1	No	Provided to communities for recovery
10	Mask "A"	Piece	1	No	Provided to communities for recovery
11	Mask "B"	Piece	1	No	Provided to communities for recovery
12	Foam rolls	Roll	1	No	Provided to communities for recovery
13	Bag of sand	Piece	Several	No	Provided to communities for recovery
14	Flashlight	Piece	1	Included	Supplied at preparedness on shelters
15	Mallet	Piece	Several	No	Provided to communities for recovery
16	Small bar	Piece	Several	No	Provided to communities for recovery
17	Chisel	Piece	Several	No	Provided to communities for recovery
18	Wheelbarrow	Piece	Several	No	Provided to communities for recovery
19	Shovel	Piece	Several	No	Provided to communities for recovery
20	Pickax	Piece	Several	No	Provided to communities for recovery
21	Helmet	Piece	Several	No	Provided to communities for recovery
22	Machete	Piece	Several	No	Provided to communities for recovery
23	Hoe	Piece	Several	No	Provided to communities for recovery
24	Axe	Piece	Several	No	Provided to communities for recovery
25	Sprayer	Piece	Several	No	Provided to communities for recovery
26	Hammer	Piece	Several	No	Provided to communities for recovery
27	Cleaning kit	Box	4	Yes	Necessary for living in shelters, supplied every month
28	Personal kit	Box	4	Yes	Necessary for living in shelters, supplied every four days
29	Feminine Hygiene towels	Piece	1	Yes	Necessary for living in shelters, supplied continuously
30	Diaper 1	Piece	1	Yes	Necessary for living in shelters, supplied continuously
31	Diaper 2	Piece	1	Yes	Necessary for living in shelters, supplied continuously
32	Diaper 3	Piece	1	Yes	Necessary for living in shelters, supplied continuously
33	Diaper 4	Piece	1	Yes	Necessary for living in shelters, supplied continuously
34	Diaper 5	Piece	1	Yes	Necessary for living in shelters, supplied continuously
35	Adult diaper	Piece	1	Yes	Necessary for living in shelters, supplied continuously
36	Baby bathtub	Piece	Several	Included	Supplied at preparedness on shelters
37	Body bag	Piece	1	No	Used for search and rescue activities
38	Neoprene gloves 20 thousandth	Pair	1	No	Provided to communities for recovery
39	Neoprene gloves 40 thousandth	Pair	1	No	Provided to communities for recovery
40	Laminate type "C"	Sheet	Several	No	Mostly used for recovery activities and houses
41	Water container	Piece	Several	Included	Supplied at preparedness on shelters
42	Mask "C"	Piece	1	No	Not crucial

On the other hand, Table F.6 displays the content of the cleaning kit, focused mostly on items for the appropriate care of the shelter and sleeping areas.

Table F.6. Products included in the cleaning kit

Product	Quantity
Chlorine	500 ml
Powder detergent	500 gr
Plastic broom	1
Squeegee for floors of 40 cm	1
Plastic tray with capacity of 19 liters	1
Cloth of one meter	1

Source: SEGOB (2012)

On the other hand, the personal kit includes items for daily personal care and bathroom items as displayed by Table F.7 and it should be replenished every four days.

Table F.7. Personal kit

Product	Quantity
Soap	200 gr
Toothpaste	100 ml/ cm^3
Toothbrush	4
Toilet paper	4

Source: SEGOB (2012)

Finally, aggregating the feminine hygiene towels and diapers a new kit labelled as hygiene kit was considered. According to CONAPO (2011) and INEGI (2010a) 27.33% of the total population was integrated by fertile women. Normally a woman would need the towels 5 days a month, meaning a probability of 1/6 per day. Therefore, considering a total of 100 people the number of towels would be around 19 towels for four days. Regarding diapers, according to INEGI (2010a) the population between 0 and 2 years represents 5.5% of the total people; therefore the aggregated need for diapers for 100 people for 4 days considering the use of 3 diapers per day would represent a total of 60 diapers distributed into the different stages. Also the adult diapers were considered for people over 70 years old, which according INEGI (2010a) represents around 4.11% of the total population, and under the same assumptions as above the number of diapers would be around 50 adult diapers. Therefore the hygiene kit contains 19 towels and 110 diapers overall, using the information from Appendix IV to provide the weight and volume.

Appendix G. Metrics of the efficient points obtained from the three cases

Veracruz

Each one of the points included in the dissertation contains a policy with individual values for each one of the decisions. Based on that, Table G.1 shows different metrics for the non-dominated points obtained on the case of Veracruz for preparedness in the first scenario.

Table G.1. Metrics of the efficient points for the preparedness scenario of 0.5 meters in Veracruz

SOL	COST ($)	AGENCIES	FILL RATE (%)				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES					SHELTERS (%)
			Food	Med	NVH	NVS	SHELTERS	DCs	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	H	TRIPS	AVG OCCUPANCY
V0ND1	399930.59	1	0.00	0.00	0.00	0.00	7	0	0.00	0.00	0.00	0.00	0	0	0	0	0	84.22
V0ND2	400956.65	1	0.00	0.00	0.00	0.00	5	0	0.00	0.00	0.00	0.00	0	0	0	0	0	97.64
V0ND3	408630.56	2	0.00	0.00	0.00	6.86	8	0	0.00	0.00	100.00	0.00	0	0	0	0	0	89.23
V0ND4	409672.31	2	0.00	0.00	0.00	6.86	4	0	0.00	0.00	100.00	0.00	0	0	0	0	0	78.52
V0ND5	436685.53	2	0.00	0.00	0.00	6.86	8	0	0.00	0.00	100.00	0.00	0	0	0	0	0	94.64
V0ND6	454102.79	2	0.00	0.00	0.00	0.86	5	1	0.00	68.18	100.00	0.00	1	0	0	0	4	93.99
V0ND7	455773.90	2	0.00	48.06	0.00	0.86	6	1	0.00	81.82	100.00	0.00	1	0	0	0	6	83.77
V0ND8	468977.84	2	0.00	4.29	0.00	1.71	5	1	0.00	90.91	100.00	0.00	1	0	0	0	5	79.83
V0ND9	476577.77	2	0.00	43.71	0.00	1.71	5	1	0.00	86.36	100.00	0.00	1	0	0	0	5	92.05
V0ND10	480348.44	2	0.00	50.91	0.00	0.86	5	1	0.00	86.36	100.00	0.00	1	0	0	0	5	86.15
V0ND11	497272.12	2	0.00	5.71	0.00	1.71	5	1	0.00	86.36	100.00	0.00	1	0	0	0	5	78.00
V0ND12	513706.49	2	0.00	39.31	0.00	1.71	6	1	0.00	86.36	100.00	0.00	1	0	0	0	6	74.07
V0ND13	515001.28	2	0.00	0.00	0.00	0.00	5	1	0.00	86.36	100.00	0.00	1	0	0	0	5	57.34
V0ND14	532330.35	2	0.00	64.34	0.00	1.71	5	1	0.00	86.36	100.00	0.00	1	0	0	0	5	58.03
V0ND15	536786.54	2	0.00	0.00	0.00	0.86	6	1	0.00	86.36	100.00	0.00	1	0	0	0	5	98.33
V0ND16	550497.75	2	0.00	4.80	0.00	1.71	6	1	0.00	86.36	100.00	0.00	1	0	0	0	5	91.33
V0ND17	587874.64	3	0.00	45.71	0.00	52.29	6	1	0.00	86.36	100.00	0.00	1	0	0	0	6	98.81
V0ND18	628170.58	2	0.00	16.86	0.00	94.46	9	2	0.00	50.00	100.00	0.00	2	0	0	0	7	99.91
V0ND19	631406.25	3	0.00	5.60	0.00	53.03	8	1	0.00	86.36	100.00	0.00	1	0	0	0	7	99.47

V0ND20	631728.32	3	0.00	0.00	0.00	52.29	8	1	0.00	86.36	100.00	0.00	1	0	0	0	8	98.71
V0ND21	658784.14	3	0.00	26.46	0.00	99.94	13	2	0.00	86.36	100.00	0.00	2	0	0	0	12	99.77
V0ND22	664491.52	3	0.00	5.37	0.00	97.14	10	2	0.00	90.91	100.00	0.00	5	0	0	0	10	98.56
V0ND23	706168.94	2	0.00	49.03	0.00	98.63	9	1	0.00	90.91	100.00	0.00	2	0	0	0	9	94.46
V0ND24	710715.26	2	0.00	4.51	0.00	100.00	5	2	0.00	86.36	100.00	0.00	3	0	0	0	5	98.78
V0ND25	737523.90	3	0.00	0.00	0.00	100.00	4	2	0.00	86.36	100.00	0.00	2	0	0	0	4	95.11
V0ND26	801428.45	2	0.00	3.66	0.00	100.00	8	1	0.00	90.91	100.00	0.00	1	0	0	0	8	93.39
V0ND27	821261.28	3	39.77	40.00	0.00	99.89	4	4	10.96	86.36	100.00	0.00	3	4	1	0	6	91.08
V0ND28	856267.49	5	9.83	9.83	0.00	88.97	11	2	17.60	86.36	100.00	0.00	3	0	3	0	11	87.31
V0ND29	898077.61	3	0.00	0.00	0.00	100.00	10	2	15.72	86.36	100.00	0.00	3	1	1	0	12	85.80
V0ND30	936597.26	4	0.00	0.00	0.00	100.00	11	4	16.80	90.91	100.00	0.00	4	2	1	0	13	82.13
V0ND31	1010376.43	5	6.40	8.34	0.00	87.94	13	2	17.28	90.91	100.00	0.00	3	0	1	0	13	94.62
V0ND32	1051407.17	3	30.40	34.29	0.00	99.20	11	2	16.84	90.91	100.00	0.00	3	1	1	0	13	91.98
V0ND33	1078680.73	4	0.00	0.00	0.00	100.00	9	4	17.08	90.91	100.00	0.00	4	1	1	0	13	90.10
V0ND34	1125810.77	2	0.00	11.26	100.00	100.00	4	1	0.00	40.48	81.43	30.70	1	0	0	1	5	96.73
V0ND35	1157096.67	2	0.00	4.57	100.00	100.00	4	1	0.00	45.24	89.87	33.33	10	0	0	0	4	82.84
V0ND36	1243754.13	3	2.97	5.14	100.00	100.00	3	1	7.12	45.24	80.26	37.72	1	0	1	0	3	69.71
V0ND37	1282073.80	3	11.43	11.43	100.00	100.00	4	1	16.96	42.86	78.64	11.40	6	1	1	0	6	66.31
V0ND38	1283376.10	3	100.00	100.00	100.00	100.00	7	1	17.60	42.86	83.50	9.65	1	2	0	0	7	100.00

As can be seen on the low-cost side metrics are very poor in other dimensions than cost, whereas increasing cost displays the inclusion of more resources to deal with demand. Similarly, Table G.2 shows the metrics for the second preparedness scenario in Veracruz, corresponding to the real scenario.

Table G.2. Metrics of the efficient points for the preparedness scenario of 1.5 meters in Veracruz

Solution	COST ($)	AGENCIES	FILL RATE (%)				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES					SHELTERS (%)	EVACUATION
			Food	Med	NVH	NVS	SHELTERS	DCs	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	H	TRIPS	AVG OCCUPANCY	DIST. P/P (MILES)
V1ND1	1176422	1	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	99.29	3.99
V1ND2	1180775	2	0	0	0	2.33	16	0	0	0	0	0	0	0	0	0	0	99.78	4.18

V1ND3	1197652	2	0	0	0	2.33	14	0	0	0	0	0	0	0	0	0	0	97.61	3.70
V1ND4	1243661	2	0	21.40	0	0.58	11	1	0	55.00	0	0	1	0	0	0	8	96.63	4.35
V1ND5	1278159	2	0	32.22	0	0.58	16	1	0	85.00	0	0	1	0	0	0	8	94.63	4.19
V1ND6	1297213	2	0	38.75	0	0.58	17	1	0	100	0	0	1	0	0	0	8	93.24	4.00
V1ND7	1313702	2	0	36.96	0	0.58	13	1	0	95.00	0	0	1	0	0	0	7	93.15	3.84
V1ND8	1345435	2	0	38.83	0	0.58	13	1	0	100	0	0	1	0	0	0	8	92.16	3.91
V1ND9	1382503	2	0	36.85	0	0.58	13	1	0	100	0	0	1	0	0	0	8	89.27	4.24
V1ND10	1419538	2	0	38.23	0	0.58	15	1	0	100	0	0	1	0	0	0	8	86.90	4.47
V1ND11	1453129	3	0	34.88	0	41.73	17	1	0	90	0	0	1	0	0	0	6	95.61	3.97
V1ND12	1472956	3	0	38.52	0	41.73	22	1	0	100	0	0	1	0	0	0	6	94.12	4.09
V1ND13	1489192	2	0	29.71	0	39.40	16	1	0	80	0	0	1	0	0	0	5	95.30	3.80
V1ND14	1520560	3	0	37.70	0	41.73	21	1	0	100	0	0	1	0	0	0	8	91.32	4.32
V1ND15	1559665	3	0	38.52	0	41.56	16	1	0	100	0	0	1	0	0	0	6	87.40	4.12
V1ND16	1593266	3	0	38.54	0	41.69	14	1	0	100	0	0	1	0	0	0	6	87.22	3.92
V1ND17	1624835	3	0	38.85	0	40.86	20	1	0	100	0	0	1	0	0	0	2	83.43	4.16
V1ND18	1662835	3	0	38.19	0	41.73	13	1	0	100	0	0	1	0	0	0	5	78.34	3.46
V1ND19	1699414	2	0	28.37	0	93.68	15	1	0	75.00	0	0	0	2	2	0	12	95.27	3.51
V1ND20	1735605	2	0	29.18	0	96.52	14	2	0	75.00	0	0	2	0	1	0	7	89.94	3.94
V1ND21	1763179	2	0	37.68	0	94.69	12	2	0	100	0	0	1	2	1	0	8	93.00	3.76
V1ND22	1804336	2	0	33.87	0	98.81	12	2	0	90	0	0	1	1	0	0	11	95.71	3.78
V1ND23	1840813	2	0	38.54	0	97.49	15	2	0	100	0	0	1	2	0	0	9	89.37	4.18
V1ND24	1873822	3	0	7.78	100	38.23	14	1	0	9.52	21.05	66.12	1	0	0	0	1	99.67	3.88
V1ND25	1910926	3	0	30.27	100	38.23	14	2	0	38.10	40.35	87.76	6	0	0	1	6	99.07	3.76
V1ND26	1945736	2	0	63.85	100	35.89	13	2	0	78.57	33.33	88.61	6	0	0	1	6	99.30	3.83
V1ND27	1980129	3	0	78.21	100	38.11	17	3	0	100	32.46	77.55	2	0	0	1	11	98.84	4.09
V1ND28	2012787	3	0	79.40	100	38.23	14	2	0	100	37.72	85.71	5	0	0	1	11	94.98	3.65
V1ND29	2051509	3	0	76.71	100	46.40	13	2	0	97.62	39.47	85.71	4	0	0	1	8	97.13	3.57
V1ND30	2086497	4	0	79.09	100	55.74	10	2	0	97.62	34.21	92.46	6	0	0	1	8	97.90	4.15

V1ND31	2121647	3	0	58.21	100	76.98	11	3	0	73.81	45.61	96.83	6	0	0	1	10	98.73	4.13
V1ND32	2155759	4	0	77.88	100	79.20	14	2	0	97.62	33.33	99.22	11	0	0	1	15	99.36	3.79
V1ND33	2155944	4	0	80.43	100	79.38	13	2	0	100	33.33	87.31	2	0	0	1	13	98.63	4.14
V1ND34	2191754	4	0	79.55	100	79.38	14	4	0	100	26.32	93.78	4	0	0	1	15	94.12	4.36
V1ND35	2226564	4	0	80.14	100	79.20	12	3	0	100	46.49	94.56	4	0	0	1	12	95.32	3.78
V1ND36	2257894	4	0	79.12	100	79.38	14	3	0	100	42.11	92.23	4	0	0	0	16	91.56	3.40
V1ND37	2288131	4	0	80.88	100	79.38	11	4	0	100	22.81	95.08	10	0	0	1	21	89.27	3.97
V1ND38	2332695	5	38.99	75.54	100	79.38	12	3	20.04	100	40.35	92.79	3	12	0	1	12	97.81	3.83
V1ND39	2367853	5	53.58	79.46	100	79.28	14	2	27.60	100	39.47	86.24	2	2	3	1	14	97.91	3.63
V1ND40	2402940	5	73.77	80.86	100	79.38	10	2	37.96	100	35.96	89.52	4	2	3	1	12	99.65	3.83
V1ND41	2438147	5	85.43	78.62	100	79.38	15	1	44.00	100	43.86	96.94	9	2	3	1	15	98.95	4.08
V1ND42	2458757	5	97.28	80.86	100	79.38	13	3	50.04	100	31.58	97.38	6	2	0	1	14	98.73	3.87
V1ND43	2473278	5	99.59	79.51	100	79.38	11	2	51.24	100	47.37	95.63	6	0	1	1	11	98.42	3.97
V1ND44	2508325	6	73.07	80.86	100	96.89	10	3	37.56	100	34.21	86.29	2	2	3	3	10	99.47	4.19
V1ND45	2543363	6	77.12	81.48	100	96.69	10	2	39.64	100	45.61	97.88	8	2	2	2	16	96.90	3.80
V1ND46	2546475	6	84.55	81.32	100	96.89	12	2	43.48	100	36.84	100	1	1	3	3	15	98.73	4.04
V1ND47	2555695	6	95.70	79.82	100	96.69	12	2	49.20	100	46.49	92.08	2	12	0	1	12	99.86	4.18
V1ND48	2560614	6	95.04	79.67	100	96.67	14	3	48.88	100	25.44	89.77	2	1	3	1	14	99.53	3.84
V1ND49	2572927	6	99.42	81.48	100	96.71	9	2	51.12	100	39.47	93.44	5	12	0	0	9	99.32	4.10
V1ND50	2580393	6	99.55	81.71	100	96.79	8	1	51.20	100	48.25	91.51	1	10	1	1	8	98.34	3.86
V1ND51	2580657	6	99.61	81.63	100	96.79	8	2	51.24	100	42.98	94.21	5	1	1	1	8	98.39	4.04
V1ND52	2592158	6	99.77	81.71	100	96.79	8	2	51.32	100	44.74	94.59	5	2	0	0	9	97.06	4.17
V1ND53	2608626	6	100	81.63	100	96.69	8	1	51.44	100	44.74	94.40	7	1	1	1	8	94.86	3.86
V1ND54	2621162	6	99.57	81.56	100	96.89	7	1	51.24	100	42.98	95.75	10	1	3	1	7	97.53	3.72
V1ND55	2625822	6	100	81.50	100	96.89	7	3	51.48	100	40.35	94.02	5	12	0	1	7	97.22	3.98
V1ND56	2626243	6	99.94	81.60	100	96.89	6	1	51.44	100	30.70	97.30	11	1	0	1	7	96.81	4.01
V1ND57	2637728	6	100	81.71	100	96.89	6	2	51.48	100	42.98	94.21	5	8	2	1	7	95.05	4.14
V1ND58	2695466	6	98.72	81.71	100	96.89	6	1	50.76	100	31.58	97.30	15	4	2	2	6	90.10	3.60

V1ND59	2698715	6	100	81.71	100	96.85	6	2	51.48	100	43.86	91.51	3	9	1	1	7	90.93	3.81
V1ND60	2706862	7	95.10	81.71	100	100	6	3	48.88	100	26.32	87.91	1	1	3	1	6	95.12	3.85
V1ND61	2748374	6	100	81.71	100	96.89	7	4	51.48	100	41.23	93.82	8	4	2	1	16	84.47	3.72
V1ND62	2786857	6	100	81.71	100	96.65	9	2	51.56	100	36.84	93.82	6	2	3	1	12	83.20	3.81
V1ND63	3070282	6	100	80.80	100	96.89	9	3	51.48	100	34.21	92.28	3	3	2	0	11	89.36	3.66
V1ND64	3103248	6	100	81.07	100	96.89	7	4	51.52	100	36.84	95.56	6	3	2	1	16	79.09	3.36
V1ND65	3103649	6	99.92	81.48	100	96.89	5	2	51.44	100	37.72	88.42	1	1	2	0	7	81.12	3.84
V1ND66	3157596	6	98.52	81.71	100	100	6	1	50.64	100	35.09	98.53	14	5	3	1	6	87.85	4.29
V1ND67	3389298	6	98.29	81.71	100	100	6	1	50.52	100	37.72	86.45	1	0	0	0	6	73.85	3.76

Finally, Table G.3 displays the metrics of the non-dominated points for the third preparedness scenario analysed.

Table G.3. Metrics of the efficient points for the preparedness scenario of 2.5 meters in Veracruz

SOL	**COST ($)**	**AGENCIES**	**FILL RATE (%)**				**FACILITIES**		**USE RELIEF ITEMS (%)**		**USE HUMAN RESOURCES (%)**		**VEHICLES**					**SHELTERS (%)**
			Food	Med	NVH	NVS	SHELTERS	DCs	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	H	TRIPS	AVG OCCUPANCY
V2ND1	1968615	1	0.00	0.00	0.00	0.00	27	0	0.00	0.00	0.00	0.00	0	0	0	0	0	96.15
V2ND2	1973287	2	0.00	0.00	0.00	1.40	27	0	0.00	0.00	0.00	100.00	0	0	0	0	0	96.37
V2ND3	1977979	2	0.00	0.00	0.00	1.40	29	0	0.00	0.00	0.00	100.00	0	0	0	0	0	95.96
V2ND4	1978164	2	0.00	0.00	0.00	1.40	27	0	0.00	0.00	0.00	100.00	0	0	0	0	0	95.77
V2ND5	1979241	2	0.00	0.00	0.00	1.40	28	0	0.00	0.00	0.00	100.00	0	0	0	0	0	95.70
V2ND6	1982452	2	0.00	0.00	0.00	1.40	27	0	0.00	0.00	0.00	100.00	0	0	0	0	0	95.56
V2ND7	1983916	2	0.00	0.00	0.00	1.40	28	0	0.00	0.00	0.00	100.00	0	0	0	0	0	95.43
V2ND8	1996085	2	0.00	0.00	0.00	1.40	28	0	0.00	0.00	0.00	100.00	0	0	0	0	0	94.69
V2ND9	2004505	2	0.00	0.00	0.00	1.40	29	0	0.00	0.00	0.00	100.00	0	0	0	0	0	94.01
V2ND10	2025665	2	0.00	0.00	0.00	1.40	30	0	0.00	0.00	0.00	100.00	0	0	0	0	0	93.10
V2ND11	2057959	2	0.00	0.00	0.00	1.40	31	0	0.00	0.00	0.00	100.00	0	0	0	0	0	90.69
V2ND12	2087417	2	0.00	8.14	0.00	0.17	31	1	0.00	35.00	0.00	100.00	1	0	0	0	6	91.02
V2ND13	2118601	2	0.00	15.12	0.00	0.35	22	1	0.00	65.00	0.00	100.00	1	0	0	0	8	90.47

V2ND14	2149508	2	0.00	19.77	0.00	0.35	21	1	0.00	85.00	0.00	100.00	1	0	0	0	8	88.87
V2ND15	2180534	2	0.00	23.26	0.00	0.35	21	1	0.00	100.00	0.00	100.00	1	0	0	0	8	87.85
V2ND16	2211145	2	0.00	23.26	0.00	0.35	21	1	0.00	100.00	0.00	100.00	1	0	0	0	6	85.83
V2ND17	2239213	2	0.00	23.24	0.00	0.34	22	1	0.00	100.00	0.00	100.00	1	0	0	0	7	85.43
V2ND18	2272452	3	0.00	23.26	0.00	24.94	23	1	0.00	100.00	0.00	100.00	1	0	0	0	8	94.64
V2ND19	2302733	3	0.00	23.23	0.00	24.42	23	1	0.00	100.00	0.00	100.00	1	0	0	0	7	91.80
V2ND20	2332034	3	0.00	21.83	0.00	24.77	21	1	0.00	100.00	0.00	100.00	1	0	0	0	7	90.18
V2ND21	2364290	3	0.00	23.26	0.00	24.94	22	1	0.00	100.00	0.00	100.00	1	0	0	0	8	89.39
V2ND22	2394646	3	0.00	22.63	0.00	24.94	22	1	0.00	100.00	0.00	100.00	1	0	0	0	8	87.35
V2ND23	2425918	3	0.00	23.26	0.00	24.42	24	1	0.00	100.00	0.00	100.00	1	0	0	0	6	87.01
V2ND24	2452662	3	0.00	22.94	0.00	24.94	23	1	0.00	100.00	0.00	100.00	1	0	0	0	7	86.33
V2ND25	2487082	3	0.00	23.26	0.00	24.42	25	1	0.00	100.00	0.00	100.00	1	0	0	0	5	85.08
V2ND26	2517483	3	0.00	10.47	0.00	62.44	20	1	0.00	45.00	0.00	100.00	1	0	0	0	4	94.01
V2ND27	2548319	3	0.00	20.91	0.00	62.44	21	1	0.00	90.00	0.00	100.00	1	0	0	0	8	93.87
V2ND28	2577679	3	0.00	23.26	0.00	62.44	20	1	0.00	100.00	0.00	100.00	1	0	0	0	5	91.88
V2ND29	2608976	3	0.00	23.00	0.00	62.97	21	1	0.00	100.00	0.00	100.00	1	0	0	0	8	89.84
V2ND30	2638808	3	0.00	23.24	0.00	62.27	21	1	0.00	100.00	0.00	100.00	0	1	0	0	4	88.76
V2ND31	2671078	2	0.00	4.65	100.00	21.45	28	1	0.00	9.52	42.11	85.23	5	0	0	0	5	95.49
V2ND32	2701856	2	0.00	19.77	100.00	21.45	27	2	0.00	40.48	35.96	80.17	3	0	0	1	17	95.55
V2ND33	2732552	2	0.00	36.05	100.00	21.45	27	2	0.00	73.81	38.60	81.01	3	0	0	1	14	96.04
V2ND34	2763148	3	0.00	46.51	100.00	22.85	27	2	0.00	95.24	44.74	88.57	5	0	0	1	12	96.00
V2ND35	2774488	3	0.00	47.67	100.00	22.85	29	2	0.00	97.62	37.72	77.55	2	0	0	0	10	95.69
V2ND36	2777870	3	0.00	47.35	100.00	22.85	28	2	0.00	100.00	37.72	85.31	5	0	0	1	12	95.37
V2ND37	2793750	3	0.00	48.26	100.00	22.85	28	3	0.00	100.00	36.84	93.06	7	0	0	1	20	94.11
V2ND38	2824455	3	0.00	47.31	100.00	22.85	19	3	0.00	97.62	35.96	95.92	10	0	0	1	10	93.31
V2ND39	2825914	3	0.00	47.69	100.00	22.85	18	2	0.00	100.00	30.70	84.08	6	0	0	1	10	93.05
V2ND40	2833092	3	0.00	48.23	100.00	22.80	22	2	0.00	100.00	33.33	88.16	7	0	0	1	9	93.80
V2ND41	2854530	3	0.00	48.45	100.00	22.85	21	2	0.00	100.00	33.33	83.27	3	0	0	1	9	91.79

V2ND42	2885355	3	0.00	48.56	100.00	22.85	22	2	0.00	100.00	34.21	77.55	2	0	0	1	9	88.93
V2ND43	2916495	3	0.00	48.41	100.00	22.85	22	2	0.00	100.00	34.21	77.55	2	0	0	1	11	88.74
V2ND44	2947157	3	0.00	45.28	100.00	45.95	28	2	0.00	97.62	40.35	86.51	1	0	0	1	10	95.52
V2ND45	2977503	3	0.00	41.78	100.00	46.05	20	2	0.00	88.10	32.46	99.74	8	0	0	1	9	94.40
V2ND46	3008431	4	0.00	48.22	100.00	47.44	21	3	0.00	100.00	34.21	86.27	2	0	0	1	11	93.82
V2ND47	3014773	4	0.00	48.34	100.00	47.44	20	1	0.00	100.00	42.98	85.49	1	0	0	0	5	93.11
V2ND48	3039167	4	0.00	48.49	100.00	47.44	21	2	0.00	100.00	32.46	85.49	3	0	0	0	10	91.10
V2ND49	3069812	4	0.00	48.66	100.00	47.44	20	2	0.00	100.00	33.33	88.08	4	0	0	1	11	89.70
V2ND50	3100176	5	0.00	45.52	100.00	57.91	19	1	0.00	95.24	47.37	96.19	7	0	0	1	5	93.80
V2ND51	3131013	5	0.00	48.48	100.00	57.91	20	3	0.00	100.00	42.11	92.60	4	0	0	1	9	91.99
V2ND52	3161113	5	0.00	48.51	100.00	57.91	19	2	0.00	100.00	33.33	92.60	6	0	0	1	13	89.81
V2ND53	3192145	3	0.00	29.62	100.00	83.95	28	3	0.00	69.05	39.47	98.49	8	0	0	1	17	95.66
V2ND54	3222489	4	0.00	44.71	100.00	85.47	27	3	0.00	97.62	40.35	96.69	6	0	0	0	28	96.32
V2ND55	3253743	3	0.00	39.72	100.00	84.07	18	2	0.00	85.71	31.58	98.99	6	0	0	1	20	93.85
V2ND56	3280781	4	0.00	45.71	100.00	85.41	21	3	0.00	100.00	34.21	93.38	3	0	0	1	19	94.14
V2ND57	3283911	4	0.00	47.38	100.00	85.47	19	3	0.00	100.00	36.84	95.03	4	0	0	1	20	93.70
V2ND58	3296317	4	0.00	47.34	100.00	85.47	22	2	0.00	100.00	42.98	95.03	3	0	0	1	22	93.83
V2ND59	3315043	4	0.00	48.74	100.00	85.47	18	2	0.00	100.00	32.46	93.54	4	0	0	1	22	90.73
V2ND60	3344819	4	0.00	48.37	100.00	85.47	20	2	0.00	100.00	33.33	95.36	6	0	0	1	20	89.62
V2ND61	3375856	4	0.00	48.72	100.00	94.33	19	2	0.00	100.00	41.23	94.82	3	0	0	1	19	94.19
V2ND62	3407003	5	0.00	47.83	100.00	95.93	19	3	0.00	100.00	42.11	96.84	5	0	0	1	21	91.98
V2ND63	3436620	5	0.00	48.15	100.00	95.84	19	3	0.00	100.00	35.09	94.28	4	0	0	0	23	89.67
V2ND64	3468444	5	28.09	48.77	100.00	85.47	19	2	24.16	100.00	33.33	100.00	3	3	0	1	22	94.07
V2ND65	3499106	5	36.28	47.03	100.00	85.47	19	2	31.20	100.00	37.72	96.01	11	3	0	0	19	94.06
V2ND66	3529767	5	42.35	47.87	100.00	85.47	20	3	36.44	100.00	40.35	96.15	6	3	0	1	21	93.55
V2ND67	3560311	5	50.65	48.56	100.00	85.47	20	2	43.56	100.00	48.25	99.85	10	3	0	1	20	93.70
V2ND68	3591072	5	58.45	47.92	100.00	85.47	20	2	50.28	100.00	36.84	96.15	8	11	0	1	21	93.73
V2ND69	3621727	5	77.62	47.38	100.00	85.43	28	2	66.80	100.00	38.60	92.01	2	5	1	0	30	95.00

V2ND70	3652362	5	88.63	47.58	100.00	85.47	28	2	76.32	100.00	46.49	97.19	8	5	1	0	30	95.89
V2ND71	3683036	5	94.70	46.29	100.00	85.35	28	3	81.52	100.00	37.72	97.93	7	3	3	1	38	95.21
V2ND72	3713650	5	90.84	48.42	100.00	85.47	20	4	78.12	100.00	33.33	100.00	6	1	1	1	23	93.71
V2ND73	3731468	5	95.36	46.80	100.00	85.41	19	2	82.04	100.00	46.49	98.22	6	12	0	1	19	93.50
V2ND74	3744363	5	97.71	48.01	100.00	85.47	18	2	84.08	100.00	33.33	96.75	5	11	0	1	20	92.90
V2ND75	3773347	5	99.84	48.78	100.00	85.47	19	2	86.00	100.00	32.46	92.31	3	10	1	1	23	91.39
V2ND76	3805711	6	88.98	46.50	100.00	95.93	20	2	76.52	100.00	35.96	92.93	4	3	1	1	23	94.21
V2ND77	3834967	6	92.36	47.66	100.00	95.93	23	1	79.48	100.00	46.49	96.88	4	10	1	1	25	93.74
V2ND78	3836377	6	92.56	48.72	100.00	95.93	18	2	79.60	100.00	43.86	94.29	3	1	1	0	19	92.40
V2ND79	3837013	6	94.70	48.74	100.00	95.92	19	2	81.44	100.00	31.58	97.96	3	3	1	0	19	93.33
V2ND80	3843405	6	96.83	48.47	100.00	95.91	19	2	83.32	100.00	33.33	96.47	8	2	3	1	22	93.23
V2ND81	3849127	6	97.05	48.42	100.00	95.93	19	2	83.48	100.00	34.21	98.91	6	3	3	1	19	93.14
V2ND82	3849609	6	97.41	48.44	100.00	95.91	19	2	83.80	100.00	35.96	96.33	8	3	0	0	21	93.28
V2ND83	3853967	6	97.33	48.77	100.00	95.93	18	2	83.72	100.00	39.47	94.70	4	3	1	1	19	92.36
V2ND84	3870831	6	96.98	48.69	100.00	95.91	19	2	83.44	100.00	32.46	97.69	8	2	1	1	19	91.51
V2ND85	3877264	6	97.09	48.79	100.00	95.91	19	3	83.52	100.00	37.72	97.96	8	1	1	0	24	91.24
V2ND86	3877976	6	97.79	48.74	100.00	95.93	19	2	84.12	100.00	31.58	92.12	2	3	0	1	19	91.17
V2ND87	3885333	6	98.10	48.79	100.00	95.93	19	2	84.40	100.00	34.21	93.21	3	12	0	1	20	90.65
V2ND88	3886894	6	98.15	48.74	100.00	95.93	18	2	84.44	100.00	35.96	94.29	5	12	0	0	18	90.08
V2ND89	3888322	6	98.55	48.84	100.00	95.91	18	2	84.76	100.00	32.46	100.00	5	12	0	0	18	90.04
V2ND90	3894454	6	99.66	48.84	100.00	95.91	18	3	85.80	100.00	35.96	96.20	6	3	3	1	27	90.04
V2ND91	3901494	6	98.22	48.84	100.00	95.93	18	3	84.52	100.00	33.33	93.89	7	2	1	0	19	88.91
V2ND92	3919553	5	92.98	48.84	100.00	100.00	18	2	79.96	100.00	36.84	94.31	4	3	1	0	19	90.98
V2ND93	3927300	6	99.81	48.81	100.00	95.87	19	3	86.12	100.00	33.33	100.00	12	3	3	1	27	88.89
V2ND94	3959033	6	100.00	48.84	100.00	95.93	19	4	86.24	100.00	33.33	95.65	7	4	3	1	29	86.90
V2ND95	3989679	5	91.91	48.84	100.00	99.94	19	1	79.04	100.00	42.98	98.64	9	1	3	1	20	87.11
V2ND96	4292582	6	99.13	48.84	100.00	95.67	12	2	85.28	100.00	42.98	98.10	9	10	1	0	22	85.86
V2ND97	4326316	6	99.81	48.84	100.00	95.93	13	2	85.96	100.00	33.33	92.53	3	5	2	1	14	84.10

V2ND98	4355068	5	93.49	48.84	100.00	100.00	13	2	80.40	100.00	36.84	92.46	5	2	1	0	15	85.44
V2ND99	4360857	5	94.09	48.77	100.00	99.92	14	2	80.92	100.00	37.72	98.39	10	2	2	1	14	85.91
V2ND100	4380941	5	95.02	48.84	100.00	100.00	14	2	81.72	100.00	28.95	94.31	5	6	3	1	15	84.84
V2ND101	4456226	5	93.81	48.84	100.00	100.00	15	2	80.68	100.00	36.84	93.57	4	2	0	0	16	79.56
V2ND102	4536837	5	94.14	48.84	100.00	100.00	16	2	80.96	100.00	38.60	97.65	9	12	0	0	16	74.83

After the application of the preparedness model for the three scenarios, the preparedness model was employed seeking to provide a policy for the deployment of resources during the rest of the flood. Table G.4 displays the results of each one of the points of the Pareto frontier obtained by applying the response model to the first scenario.

Table G.4. Metrics of the efficient points for the response scenario of 0.5 meters in Veracruz

SOL	COST	FILL RATE (%)					SERVICE UNFULFILLMENT		AGENCIES (per period)				PRODUCTS SUPPLIED					MAXIMUM PERSONNEL P/PERIOD				MAXIMUM VEHICLES P/PERIOD				
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MEDI	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	H	TRIPS
R0V1	362262.9	81.04	100	51.17	50.76	23.36	5026	4576	2	2	2	16	971	0	175	641	20	7	65	0	6	1	10	0	0	7
R0V2	378624.8	81.00	100	51.17	50.64	100	5026	4576	2	2	2	12	971	0	175	641	72	17	55	0	6	2	2	3	0	7
R0V3	384884.7	80.96	100	51.17	50.64	100	5026	4456	3	2	3	13	971	0	175	641	72	18	54	0	8	3	1	3	0	7
R0V4	385049	81.10	100	51.17	50.52	100	5026	4456	3	2	3	13	971	0	175	641	72	50	22	0	8	1	1	1	0	13
R0V5	389892	83.27	100	51.17	50.99	100	5026	4456	3	2	3	13	999	0	175	642	72	6	66	0	8	3	3	3	0	7
R0V6	417782.4	95.30	100	51.17	51.13	100	5026	4456	3	2	3	13	1157	0	175	643	72	18	54	0	8	3	1	3	0	7
R0V7	445672.7	100	100	51.17	68.70	100	5026	4456	3	2	3	13	1220	0	175	873	72	11	61	0	8	3	4	2	0	7
R0V8	473559.8	100	100	51.17	98.65	100	5026	4456	3	2	3	13	1220	0	175	1255	72	4	68	0	8	1	5	3	0	7
R0V9	501495.1	85.73	100	51.17	50.72	100	5026	3556	4	2	3	14	1030	0	175	642	72	28	44	0	68	1	1	3	0	7
R0V10	529371.8	97.69	100	51.17	50.92	100	5026	3556	4	2	3	14	1188	0	175	643	72	61	11	0	68	1	1	0	0	7
R0V11	557281.2	100	100	51.17	74.85	100	5026	3556	3	2	3	14	1220	0	175	948	72	61	11	0	66	1	1	0	0	7
R0V12	585172.5	81.38	100	51.17	50.92	100	5026	2896	3	2	3	13	974	0	175	641	72	50	22	0	58	1	1	1	0	7
R0V13	613075.1	88.30	100	51.17	50.88	100	5026	2656	4	2	3	15	1061	0	175	642	72	18	54	0	68	3	1	3	0	7
R0V14	640997.7	100	100	51.17	50.96	100	5026	2656	4	2	3	15	1220	0	175	641	72	61	11	0	68	1	1	0	0	7
R0V15	668896.4	100	100	51.17	80.68	100	5026	2656	4	2	3	15	1220	0	175	1023	72	7	65	0	68	1	10	0	0	7

R0V16	696794	81.16	100	51.17	50.88	98.13	5026	1876	3	2	3	15	971	0	175	642	71	50	22	0	66	1	1	1	0	7
R0V17	703298.6	81.08	100	51.17	50.82	100	5026	1756	4	2	3	16	971	0	175	641	72	18	54	0	68	3	1	3	0	7
R0V18	724695.3	90.41	100	51.17	51.09	100	5026	1756	4	2	3	16	1092	0	175	642	72	56	16	0	68	1	0	1	0	8
R0V19	747160.5	100	100	51.17	50.78	100	5026	1756	4	2	3	16	1220	0	175	641	72	28	44	0	68	1	1	3	0	8
R0V20	752554.1	100	100	51.17	56.33	100	5026	1756	4	2	3	16	1220	0	175	715	72	50	22	0	68	1	1	1	0	8
R0V21	780498.1	100	100	51.17	86.39	100	5026	1756	4	2	3	16	1220	0	175	1098	72	50	22	0	68	1	1	1	0	7
R0V22	808360.6	91.56	100	51.17	50.92	100	5026	1216	4	2	3	17	1110	0	175	642	72	61	11	0	68	1	1	0	0	7
R0V23	827676.2	100	100	51.17	50.60	100	5026	1216	4	2	3	17	1220	0	175	641	72	50	22	0	68	1	1	1	0	8
R0V24	836261	100	100	51.17	59.81	100	5026	1216	4	2	3	17	1220	0	175	759	72	61	11	0	68	1	1	0	0	7
R0V25	864147.1	100	100	51.17	89.73	100	5026	1216	4	2	3	17	1220	0	175	1141	72	61	11	0	68	1	1	0	0	7
R0V26	873778.5	100	100	51.17	100	100	5026	1216	4	2	3	17	1220	0	175	1273	72	4	68	0	68	1	5	3	0	7
R0V27	892047.6	100	100	51.17	98.85	100	5026	1120	4	2	3	16	1220	0	175	1258	72	61	11	0	68	1	1	0	0	7
R0V28	919930.4	100	100	51.17	75.67	100	5026	868	3	2	3	16	1220	0	175	966	72	61	11	0	141	1	1	0	0	7
R0V29	942415.2	100	100	51.17	100	100	5026	869	3	2	3	16	1220	0	175	1273	72	11	61	0	141	3	4	2	0	7
R0V30	947876.6	100	100	62.57	100	100	5026	868	3	2	3	16	1220	0	216	1273	72	61	11	0	141	1	1	0	0	7
R0V31	961776.3	100	100	51.17	100	100	5026	772	3	2	3	15	1220	0	175	1273	72	55	22	0	136	1	1	1	0	9
R0V32	975741.2	100	100	80.77	100	100	5026	772	3	2	3	15	1220	0	279	1273	72	28	44	0	141	1	1	3	0	7
R0V33	1003684	100	100	51.17	92.32	100	5026	557	3	2	3	15	1220	0	175	1174	72	61	11	0	141	1	1	0	0	7
R0V34	1010918	100	100	51.17	100	100	5026	557	3	2	3	15	1220	0	175	1273	72	33	84	0	96	10	1	3	0	7
R0V35	1030276	100	100	51.17	100	100	5026	461	3	2	3	14	1220	0	175	1273	72	6	66	0	141	3	3	3	0	7
R0V36	1031543	100	100	53.87	99.96	100	5026	461	3	2	3	14	1220	0	185	1272	72	61	11	0	141	1	1	0	0	7
R0V37	1053379	100	100	100	100	100	5026	461	3	2	3	14	1220	0	346	1273	72	4	69	0	141	2	8	1	0	9
R0V38	1087314	100	100	55.63	100	100	5026	354	3	2	3	15	1220	0	191	1273	72	52	54	0	141	3	1	3	0	7
R0V39	1115281	100	100	73.76	99.98	100	5026	258	3	2	3	14	1220	0	255	1272	72	61	11	0	141	1	1	0	0	8
R0V40	1139551	100	100	100	100	100	5026	258	5	2	3	16	1220	0	346	1273	72	2	70	0	139	1	9	1	0	7
R0V41	1171038	100	100	51.17	97.81	100	5026	141	3	2	3	13	1220	0	175	1245	72	64	44	0	141	1	1	3	0	7
R0V42	1198998	100	100	94.08	100	100	5026	117	3	2	3	14	1220	0	325	1273	72	52	44	0	141	1	2	3	0	7
R0V43	1226327	100	100	100	100	100	5026	117	4	2	3	18	1220	0	346	1273	72	50	22	0	149	1	1	1	0	7

R0V44	1254738	100	100	66.89	100	100	5026	0	3	2	3	13	1220	0	230	1273	72	18	99	0	139	12	1	3	0	7
R0V45	1282367	100	100	100	100	100	5026	0	3	2	3	15	1220	0	346	1273	72	28	44	0	147	1	1	3	0	8
R0V46	1394300	100	100	51.17	52.63	100	3658	868	3	2	3	16	1220	0	175	668	72	51	25	10	95	3	1	0	1	7
R0V47	1422188	100	100	51.17	82.49	100	3658	868	3	2	3	16	1220	0	175	1050	72	61	15	10	95	1	1	0	1	7
R0V48	1450099	100	100	51.17	91.68	100	3658	772	3	2	3	15	1220	0	175	1167	72	66	15	10	95	1	1	0	1	7
R0V49	1477999	100	100	94.08	99.98	100	3658	772	3	2	3	15	1220	0	325	1272	72	51	105	10	95	19	1	0	1	7
R0V50	1505878	100	100	51.17	98.77	100	3658	557	3	2	3	15	1220	0	175	1257	72	60	61	10	139	9	2	0	1	7
R0V51	1533752	100	100	67.11	99.98	100	3658	461	3	2	3	14	1220	0	230	1272	72	61	15	10	139	1	1	0	1	7
R0V52	1549527	100	100	100	100	100	3658	461	3	2	3	14	1220	0	346	1273	72	9	67	10	139	1	6	2	1	7
R0V53	1589576	100	100	51.17	88.52	100	3658	258	3	2	3	14	1220	0	175	1121	72	40	36	10	134	3	1	1	1	8
R0V54	1617442	100	100	86.70	100	100	3658	258	3	2	3	14	1220	0	299	1273	72	22	54	10	95	10	2	3	1	10
R0V55	1624045	100	100	100	100	100	3658	258	3	2	3	14	1220	0	346	1273	72	33	83	10	139	8	1	3	1	11
R0V56	1673280	100	100	51.17	98.29	100	3658	117	3	2	3	14	1220	0	175	1251	72	61	15	10	95	1	1	0	1	7
R0V57	1698282	100	100	100	100	100	3658	117	3	2	3	14	1220	0	346	1273	72	33	48	10	139	2	2	3	1	13
R0V58	1756975	100	100	79.61	100	100	3658	0	3	2	3	13	1220	0	275	1273	72	52	70	10	139	0	11	0	1	7
R0V59	1778568	100	100	100	100	100	3658	0	3	2	3	15	1220	0	346	1273	72	55	21	10	139	1	2	0	1	9
R0V60	1924391	85.59	100	51.17	50.78	100	2357	557	3	2	3	15	1034	0	175	642	72	55	21	10	95	1	2	0	1	8
R0V61	1952275	98.11	100	51.17	50.50	100	2357	557	3	2	3	15	1193	0	175	641	72	6	70	10	95	3	3	3	1	7
R0V62	1980188	100	100	51.17	75.03	100	2357	557	3	2	3	15	1220	0	175	958	72	6	165	10	95	19	11	0	1	7
R0V63	2008046	100	100	61.48	100	100	2357	557	3	2	3	15	1220	0	211	1273	72	45	31	10	95	3	2	0	1	8
R0V64	2035868	100	100	79.53	100	100	2357	461	3	2	3	14	1220	0	274	1273	72	33	134	10	95	19	1	3	0	7
R0V65	2045627	100	100	100	100	100	2357	461	3	2	3	14	1220	0	346	1273	72	51	122	10	95	19	2	1	1	7
R0V66	2091799	100	100	51.17	94.63	100	2357	258	3	2	3	14	1220	0	175	1205	72	55	26	10	95	1	1	1	1	7
R0V67	2119699	100	100	99.93	100	100	2357	258	3	2	3	14	1220	0	345	1273	72	66	15	10	95	1	1	0	1	7
R0V68	2119860	100	100	100	100	100	2357	258	3	2	3	14	1220	0	346	1273	72	33	118	10	95	15	1	3	1	8
R0V69	2175484	100	100	60.82	100	100	2357	117	3	2	3	14	1220	0	208	1273	72	33	143	10	95	20	2	3	1	8
R0V70	2194216	100	100	100	100	100	2357	117	3	2	3	14	1220	0	346	1273	72	49	57	10	95	6	2	1	1	9
R0V71	2259144	100	100	92.98	100	100	2357	0	3	2	3	13	1220	0	320	1273	72	64	149	10	95	20	2	3	1	7

R0V72	2274603	100	100	100	100	100	2357	0	3	2	3	15	1220	0	346	1273	72	23	53	10	95	2	3	3	1	8
R0V73	2482384	100	100	51.17	94.71	100	1250	980	3	2	3	13	1220	0	175	1205	72	3	174	10	95	23	6	3	1	7
R0V74	2510266	95.09	100	51.17	50.60	100	1250	440	3	2	3	14	1155	0	175	641	72	66	115	10	95	23	1	0	0	7
R0V75	2538189	100	100	51.17	68.30	100	1250	440	3	2	3	14	1220	0	175	867	72	33	148	10	95	23	1	3	1	7
R0V76	2566080	100	100	51.17	98.21	100	1250	440	3	2	3	14	1220	0	175	1249	72	66	116	10	95	23	1	0	0	7
R0V77	2593978	100	100	65.20	100	100	1250	344	3	2	3	13	1220	0	225	1273	72	27	159	10	95	22	2	3	1	8
R0V78	2611592	100	100	100	100	100	1250	344	3	2	3	13	1220	0	346	1273	72	33	153	10	95	22	1	3	1	10
R0V79	2649772	100	100	67.40	100	100	1250	237	3	2	3	14	1220	0	232	1273	72	2	186	10	95	22	12	0	1	7
R0V80	2677670	100	100	85.23	100	100	1250	141	3	2	3	13	1220	0	295	1273	72	5	183	10	95	22	6	3	1	7
R0V81	2684547	100	100	100	100	100	1250	141	3	2	3	13	1220	0	346	1273	72	6	186	10	95	27	3	3	1	9
R0V82	2684593	100	100	100	100	100	1250	141	3	2	3	13	1220	0	346	1273	72	66	65	10	95	11	1	0	1	9
R0V83	2733481	100	100	51.17	97.67	100	1250	0	3	2	3	13	1220	0	175	1243	72	5	183	10	95	23	6	3	1	7
R0V84	2758813	100	100	100	100	100	1250	0	3	2	3	13	1220	0	346	1273	72	33	73	10	95	6	1	3	1	9
R0V85	3124047	100	100	51.17	63.49	100	524	344	3	2	3	13	1220	0	175	806	72	51	65	10	95	11	1	0	1	7
R0V86	3151972	100	100	51.17	93.31	100	524	344	3	2	3	13	1220	0	175	1188	72	55	137	10	95	24	1	1	1	8
R0V87	3179898	100	100	97.30	100	100	524	344	3	2	3	13	1220	0	336	1273	72	28	48	10	95	1	1	3	1	8
R0V88	3182018	100	100	100	100	100	524	344	3	2	3	13	1220	0	346	1273	72	2	74	10	95	0	8	2	1	7
R0V89	3235677	100	100	57.82	100	100	524	141	3	2	3	13	1220	0	199	1273	72	12	189	10	95	24	6	3	0	7
R0V90	3261992	100	100	100	100	100	524	141	3	2	3	14	1220	0	346	1273	72	28	48	10	95	1	1	3	1	14
R0V91	3319374	100	100	77.63	100	100	524	0	3	2	3	13	1220	0	269	1273	72	12	189	10	95	23	8	2	1	7
R0V92	3329726	100	100	100	100	100	524	0	3	2	3	13	1220	0	346	1273	72	12	188	10	95	23	6	3	1	9
R0V93	3821599	100	100	51.17	92.06	100	231	141	3	2	3	13	1220	0	175	1172	72	3	158	10	95	17	6	3	1	7
R0V94	3849494	100	100	94.88	100	100	231	141	3	2	3	13	1220	0	327	1273	72	33	48	10	95	1	1	3	1	8
R0V95	3852473	100	100	100	100	100	231	141	3	2	3	13	1220	0	346	1273	72	61	15	10	95	1	1	0	1	14
R0V96	3905287	100	100	55.34	100	100	231	0	3	2	3	13	1220	0	190	1273	72	4	120	10	95	24	5	3	1	8
R0V97	3926399	100	100	100	100	100	231	0	3	2	3	13	1220	0	346	1273	72	33	48	10	95	1	1	3	1	10
R0V98	4491195	100	100	51.17	91.07	100	0	0	3	2	3	13	1220	0	175	1155	72	50	26	10	95	1	1	1	1	7
R0V99	4519097	100	100	92.62	100	100	0	0	3	2	3	13	1220	0	318	1273	72	5	188	10	95	23	6	3	1	8

R0V100	4522990	100	100	100	100	100	0	0	3	2	3	13	1220	0	346	1273	72	5	188	10	95	23	6	3	1	12

Similarly, Table G.5 contains the analysis of the solutions obtained on the application of the response model to the second scenario.

Table G.5. Metrics of the efficient points for the response scenario of 1.5 meters in Veracruz

SOL	COST	FILL RATE (%)					People not served		AGENCIES (per period)				PRODUCTS SUPPLIED					MAXIMUM PERSONNEL P/PERIOD				MAXIMUM VEHICLES P/PERIOD				
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	H	TRIPS
R1V1	910664.7	80.33	100	50.29	50.17	24.50	14756	14126	3	2	3	18	2809	2	505	1855	38	6	70	0	32	3	3	3	1	7
R1V2	944168.3	80.36	100	50.29	50.14	87.66	14756	14126	3	2	3	13	2810	2	505	1855	144	8	68	0	32	1	8	1	1	6
R1V3	951269.5	80.31	100	50.29	50.09	100	14756	14126	3	2	3	13	2809	2	505	1855	167	6	70	0	32	3	3	3	1	7
R1V4	957502.6	80.30	100	50.29	50.18	100	14756	14006	4	2	3	14	2809	2	505	1855	167	6	70	0	40	3	3	3	1	6
R1V5	957515	80.31	100	50.29	50.14	100	14756	14006	4	2	3	14	2809	2	505	1855	167	9	67	0	40	2	7	1	1	7
R1V6	977397.8	83.37	100	50.29	50.23	100	14756	14006	4	2	3	14	2922	2	505	1855	167	18	58	0	40	3	1	3	1	7
R1V7	1010587	88.44	100	50.29	50.18	100	14756	14006	4	2	3	14	3110	2	505	1856	167	50	26	0	40	1	1	1	1	7
R1V8	1043772	93.48	100	50.29	50.23	100	14756	14006	4	2	3	14	3299	2	505	1855	167	12	64	0	40	3	2	3	1	6
R1V9	1076989	82.38	100	50.29	50.28	100	14756	13106	4	2	3	15	2884	2	505	1857	167	56	20	0	62	2	1	0	1	7
R1V10	1110187	80.33	100	50.29	50.16	69.35	14756	12131	3	2	3	13	2810	2	505	1856	116	7	69	0	135	1	10	0	1	8
R1V11	1143392	81.12	100	50.29	50.16	100	14756	11891	5	2	3	15	2837	2	505	1855	167	40	36	0	181	3	1	1	1	6
R1V12	1176593	86.15	100	50.29	50.24	100	14756	11891	4	2	3	15	3025	2	505	1856	167	49	27	0	143	0	2	1	1	6
R1V13	1209776	91.22	100	50.29	50.19	100	14756	11891	4	2	3	15	3214	2	505	1855	167	9	67	0	143	0	5	3	1	6
R1V14	1242985	80.39	100	50.29	50.23	95.95	14756	10991	4	2	3	16	2810	2	505	1856	161	6	70	0	143	0	11	0	1	7
R1V15	1276195	85.20	100	50.29	50.22	100	14756	10991	5	2	3	16	2988	2	505	1856	167	49	27	0	181	0	2	1	1	6
R1V16	1309369	80.75	100	50.29	50.18	100	14756	10016	4	2	3	14	2823	2	505	1855	167	7	69	0	173	0	9	1	1	6
R1V17	1342568	83.88	100	50.29	50.24	100	14756	9776	5	2	3	16	2940	2	505	1856	167	50	26	0	181	1	1	1	1	6
R1V18	1375779	88.91	100	50.29	50.14	100	14756	9776	5	2	3	16	3129	2	505	1855	167	6	70	0	181	3	3	3	1	6
R1V19	1408973	94.02	100	50.29	50.21	100	14756	9776	5	2	3	16	3317	2	505	1856	167	45	31	0	181	2	1	1	1	7
R1V20	1442199	82.84	100	50.29	50.22	100	14756	8876	4	2	3	17	2903	2	505	1856	167	9	67	0	143	2	7	1	1	7

R1V21	1475345	80.37	100	50.29	50.24	100	14756	8141	3	2	3	13	2809	2	505	1855	167	7	69	0	135	1	10	0	1	7
R1V22	1508572	81.51	100	50.29	50.21	100	14756	7661	5	2	3	17	2855	2	505	1856	167	8	68	0	181	1	8	1	1	6
R1V23	1541799	86.66	100	50.29	50.20	100	14756	7661	5	2	3	17	3044	2	505	1855	167	54	22	0	181	0	3	0	1	7
R1V24	1574956	91.64	100	50.29	50.24	100	14756	7661	5	2	3	17	3232	2	505	1856	167	8	68	0	181	2	9	0	1	7
R1V25	1608194	80.62	100	50.29	50.18	100	14756	6761	5	2	3	18	2818	2	505	1856	167	28	48	0	181	1	1	3	1	6
R1V26	1641396	85.61	100	50.29	50.15	100	14756	6761	5	2	3	18	3007	2	505	1855	167	50	26	0	181	1	1	1	1	6
R1V27	1674574	80.37	100	50.29	50.28	99.17	14756	5666	5	2	3	17	2809	2	505	1856	165	7	69	0	181	0	9	1	1	6
R1V28	1681398	80.34	100	50.29	50.19	100	14756	5563	5	2	3	18	2809	2	505	1855	167	49	27	0	181	0	2	1	1	6
R1V29	1707778	84.44	100	50.29	50.19	100	14756	5563	5	2	3	18	2959	2	505	1855	167	8	68	0	181	1	8	1	1	6
R1V30	1740959	89.43	100	50.29	50.22	100	14756	5563	5	2	3	18	3147	2	505	1856	167	49	27	0	181	0	2	1	1	6
R1V31	1774199	94.40	100	50.29	50.14	100	14756	5563	5	2	3	18	3336	2	505	1855	167	50	26	0	181	1	1	1	1	7
R1V32	1807400	83.36	100	50.29	50.18	100	14756	4663	5	2	4	19	2922	2	505	1855	167	50	26	0	203	1	1	1	1	6
R1V33	1840592	88.38	100	50.29	50.21	100	14756	4663	5	2	4	19	3110	2	505	1856	167	6	70	0	203	3	3	3	1	6
R1V34	1873790	93.52	100	50.29	50.15	100	14756	4663	6	2	4	19	3299	2	505	1855	167	14	62	0	241	1	7	1	1	7
R1V35	1906991	82.34	100	50.29	50.20	100	14756	3763	6	2	4	20	2884	2	505	1857	167	50	26	0	241	1	1	1	1	6
R1V36	1940194	87.37	100	50.29	50.18	100	14756	3763	6	2	4	20	3073	2	505	1856	167	28	48	0	241	1	1	3	1	6
R1V37	1973396	92.42	100	50.29	50.12	100	14756	3763	5	2	4	20	3262	2	505	1855	167	50	26	0	203	1	1	1	1	6
R1V38	2006569	81.32	100	50.29	50.12	100	14756	2863	6	2	4	21	2847	2	505	1856	167	50	26	0	241	2	2	0	1	7
R1V39	2039796	86.39	100	50.29	50.21	100	14756	2863	6	2	4	21	3036	2	505	1855	167	55	21	0	241	1	2	0	1	8
R1V40	2072988	91.40	100	50.29	50.16	100	14756	2863	6	2	4	21	3224	2	505	1857	167	28	48	0	241	1	1	3	1	6
R1V41	2106171	80.39	100	50.29	50.29	100	14756	2034	6	2	4	22	2810	2	505	1856	167	38	38	0	241	0	2	2	1	6
R1V42	2139383	85.40	100	50.29	50.14	100	14756	2034	6	2	4	22	2999	2	505	1855	167	55	21	0	241	1	2	0	1	7
R1V43	2172583	90.40	100	50.29	50.17	100	14756	2034	6	2	4	22	3187	2	505	1856	167	11	65	0	241	2	3	3	1	8
R1V44	2205765	95.54	100	50.29	50.16	100	14756	2034	6	2	4	22	3376	2	505	1855	167	50	26	0	241	1	1	1	1	7
R1V45	2238942	100	100	50.29	51.30	100	14756	2034	6	2	4	22	3545	2	505	1898	167	56	20	0	241	2	1	0	1	8
R1V46	2272187	80.41	100	50.29	50.24	100	10739	4318	4	2	3	17	2811	2	505	1857	167	47	31	17	264	2	1	1	1	7
R1V47	2278003	80.35	100	50.29	50.16	100	10739	4261	5	2	3	18	2809	2	505	1855	167	6	75	17	270	4	3	3	1	7
R1V48	2305392	84.53	100	50.29	50.34	100	10739	4261	5	2	3	18	2964	2	505	1857	167	49	27	17	272	0	2	1	1	6

R1V49	2338585	89.45	100	50.29	50.18	100	10739	4261	5	2	3	18	3153	2	505	1856	167	6	80	17	270	1	10	1	1	6
R1V50	2371797	80.35	100	50.29	50.11	100	10739	3521	4	2	3	17	2810	2	505	1856	167	50	26	17	264	1	1	1	1	6
R1V51	2404941	83.54	100	50.29	50.28	100	10739	3361	5	2	4	19	2927	2	505	1856	167	53	27	17	272	0	2	1	1	6
R1V52	2438187	88.59	100	50.29	50.15	100	10739	3361	5	2	4	19	3116	2	505	1855	167	44	32	17	270	1	2	1	1	8
R1V53	2471389	93.54	100	50.29	50.22	100	10739	3361	5	2	4	19	3304	2	505	1857	167	22	65	17	270	2	3	3	1	7
R1V54	2490288	80.31	100	50.29	50.13	100	10739	2461	5	2	4	20	2809	2	505	1855	167	6	73	17	270	0	6	3	1	7
R1V55	2504598	82.48	100	50.29	50.18	100	10739	2461	5	2	4	20	2890	2	505	1856	167	60	26	17	270	2	2	0	1	8
R1V56	2537785	87.55	100	50.29	50.16	100	10739	2461	5	2	4	20	3079	2	505	1855	167	27	49	17	272	0	2	3	1	6
R1V57	2570953	92.61	100	50.29	50.20	100	10739	2461	5	2	4	20	3267	2	505	1856	167	43	33	17	272	0	3	1	1	7
R1V58	2604175	81.52	100	50.29	50.24	100	10739	1632	5	2	4	21	2853	2	505	1856	167	50	26	17	272	1	1	1	1	6
R1V59	2637387	86.53	100	50.29	50.12	100	10739	1632	5	2	4	21	3042	2	505	1855	167	60	20	17	270	2	1	0	1	7
R1V60	2670579	91.55	100	50.29	50.18	100	10739	1632	5	2	4	21	3230	2	505	1856	167	53	27	17	270	0	2	1	1	6
R1V61	2703782	96.65	100	50.29	50.19	100	10739	1632	5	2	4	21	3419	2	505	1855	167	31	49	17	270	0	2	3	1	6
R1V62	2736968	100	100	50.29	54.17	100	10739	1632	5	2	4	21	3545	2	505	2002	167	22	58	17	272	3	1	3	1	7
R1V63	2770183	100	100	50.29	66.39	100	10739	1632	5	2	4	21	3545	2	505	2457	167	40	36	17	270	3	1	1	1	7
R1V64	2803370	99.47	100	50.29	50.18	100	10739	1092	5	2	4	22	3525	2	505	1857	167	50	26	17	270	1	1	1	1	7
R1V65	2836574	100	100	50.29	61.10	100	10739	1092	5	2	4	22	3545	2	505	2263	167	10	72	17	270	2	6	2	1	9
R1V66	2869799	97.39	100	50.29	50.14	100	10739	552	5	3	4	23	3447	2	505	1856	167	6	70	17	272	3	3	3	1	7
R1V67	2902992	99.99	100	50.29	56.13	100	10739	552	5	3	4	23	3544	2	505	2073	167	54	26	17	270	1	1	1	1	7
R1V68	2936175	80.31	100	50.29	50.20	99.95	6919	2746	4	2	3	16	2810	2	505	1856	166	67	65	17	264	13	1	0	1	7
R1V69	2969375	83.44	100	50.29	50.16	100	6919	2586	5	2	3	18	2926	2	505	1855	167	12	64	17	270	3	2	3	1	6
R1V70	3002562	88.48	100	50.29	50.20	100	6919	2586	5	2	3	18	3114	2	505	1856	167	48	32	17	270	0	1	2	1	6
R1V71	3035787	93.56	100	50.29	50.19	100	6919	2586	5	2	3	18	3303	2	505	1855	167	48	32	17	270	1	2	1	1	7
R1V72	3054947	80.30	100	50.29	50.12	100	6919	1686	5	2	4	19	2809	2	505	1855	167	8	159	17	272	17	8	2	1	6
R1V73	3068988	82.47	100	50.29	50.16	100	6919	1686	5	2	4	19	2889	2	505	1855	167	50	26	17	270	1	1	1	1	6
R1V74	3075379	83.34	100	50.29	50.16	100	6919	1686	5	2	4	19	2922	2	505	1855	167	15	66	17	270	2	5	2	1	13
R1V75	3102160	87.45	100	50.29	50.20	100	6919	1686	5	2	4	19	3077	2	505	1856	167	54	26	17	272	1	1	1	1	6
R1V76	3135389	92.55	100	50.29	50.17	100	6919	1686	5	2	4	19	3266	2	505	1855	167	6	75	17	272	4	3	3	1	7

R1V77	3168589	81.43	100	50.29	50.19	100	6919	857	5	2	4	20	2851	2	505	1857	167	70	99	17	270	19	1	0	1	7
R1V78	3201791	86.45	100	50.29	50.16	100	6919	857	5	2	4	20	3040	2	505	1856	167	31	49	17	272	0	2	3	1	6
R1V79	3234984	91.50	100	50.29	50.24	100	6919	857	5	2	4	20	3229	2	505	1855	167	10	72	17	270	3	7	1	1	6
R1V80	3268157	96.60	100	50.29	50.20	100	6919	857	5	2	4	20	3417	2	505	1856	167	9	68	17	270	1	8	1	1	6
R1V81	3290950	100	100	50.29	50.19	100	6919	857	5	2	4	20	3545	2	505	1855	167	55	87	17	272	12	2	1	1	8
R1V82	3301400	100	100	50.29	54.04	100	6919	857	5	2	4	20	3545	2	505	1998	167	7	95	17	272	4	10	1	1	8
R1V83	3334575	100	100	50.29	66.26	100	6919	857	5	2	4	20	3545	2	505	2453	167	54	26	17	272	1	1	1	1	7
R1V84	3367741	99.46	100	50.29	50.18	100	6919	317	5	3	4	21	3524	2	505	1855	167	59	26	17	270	1	1	1	1	8
R1V85	3371464	100	100	50.29	50.14	100	6919	317	5	3	4	21	3545	2	505	1855	167	55	112	17	272	17	2	1	1	8
R1V86	3400994	100	100	50.29	61.12	100	6919	317	5	3	4	21	3545	2	505	2260	167	6	80	17	270	1	10	1	1	7
R1V87	3434136	100	100	50.29	73.32	100	6919	317	5	3	4	21	3545	2	505	2714	167	7	73	17	270	1	7	2	1	7
R1V88	3467361	100	100	50.29	85.53	100	6919	317	5	3	4	21	3545	2	505	3169	167	70	60	17	272	10	1	0	1	8
R1V89	3500594	100	100	50.29	97.85	100	6919	317	5	3	4	21	3545	2	505	3624	167	50	26	17	272	1	1	1	1	8
R1V90	3533731	100	100	56.16	100	100	6919	209	5	2	4	20	3545	2	564	3704	167	61	46	17	270	5	1	1	1	7
R1V91	3566942	100	100	80.51	100	100	6919	209	5	2	4	20	3545	2	810	3704	167	39	73	17	272	6	1	3	1	7
R1V92	3593930	100	100	100	100	100	6919	209	5	2	4	20	3545	2	1007	3704	167	54	94	17	270	18	2	0	1	12
R1V93	3633397	92.82	100	50.29	50.22	100	3669	1866	5	2	4	19	3276	2	505	1857	167	60	20	17	272	2	1	0	1	7
R1V94	3666580	81.65	100	50.29	50.18	100	3669	1037	5	2	4	20	2862	2	505	1856	167	10	70	17	270	9	11	0	1	7
R1V95	3699764	86.79	100	50.29	50.14	100	3669	1037	5	2	4	20	3051	2	505	1855	167	48	37	17	272	1	1	2	1	6
R1V96	3732966	91.82	100	50.29	50.15	100	3669	1037	5	2	4	20	3239	2	505	1856	167	9	67	17	270	0	5	3	1	6
R1V97	3766179	96.88	100	50.29	50.13	100	3669	1037	5	2	4	20	3428	2	505	1855	167	42	38	17	270	0	2	2	1	6
R1V98	3799386	100	100	50.29	54.70	100	3669	1037	5	2	4	20	3545	2	505	2024	167	6	80	17	272	3	11	0	1	8
R1V99	3832592	94.74	100	50.29	50.14	100	3669	497	5	3	4	21	3348	2	505	1855	167	47	31	17	272	3	2	0	1	7
R1V100	3865797	99.75	100	50.29	50.12	100	3669	497	5	3	4	21	3535	2	505	1855	167	27	53	17	270	2	1	3	1	8
R1V101	3867614	100	100	50.29	50.09	100	3669	497	5	3	4	21	3545	2	505	1855	167	9	73	17	272	4	6	3	1	7
R1V102	3898978	100	100	50.29	61.74	100	3669	497	5	3	4	21	3545	2	505	2285	167	6	74	17	272	0	8	2	1	7
R1V103	3932153	100	100	50.29	74.01	100	3669	497	5	3	4	21	3545	2	505	2740	167	59	36	17	272	3	1	1	1	7
R1V104	3965368	100	100	50.29	86.28	100	3669	497	5	3	4	21	3545	2	505	3195	167	50	89	17	272	17	1	1	1	7

R1V105	3998583	100	100	50.29	98.56	100	3669	497	5	3	4	21	3545	2	505	3650	167	50	26	17	270	1	1	1	1	7
R1V106	4002562	100	100	50.29	100	100	3669	497	5	3	4	21	3545	2	505	3704	167	6	74	17	270	4	9	1	1	8
R1V107	4022027	100	100	50.29	100	100	3669	389	5	2	4	20	3545	2	505	3704	167	46	87	17	270	11	1	2	1	11
R1V108	4031743	100	100	50.29	85.44	100	3669	112	5	3	4	20	3545	2	505	3165	167	56	69	17	272	13	1	1	1	7
R1V109	4064986	100	100	50.29	97.76	100	3669	112	5	3	4	20	3545	2	505	3620	167	56	26	17	270	1	1	1	1	8
R1V110	4090450	100	100	50.29	100	100	3669	4	5	2	4	19	3545	2	505	3704	167	61	86	17	272	13	1	1	1	7
R1V111	4098145	100	100	55.96	100	100	3669	4	5	2	4	19	3545	2	562	3704	167	9	70	17	272	3	3	3	1	7
R1V112	4131379	100	100	80.33	100	100	3669	4	5	2	4	19	3545	2	808	3704	167	44	32	17	270	0	1	2	1	7
R1V113	4159046	100	100	100	100	100	3669	4	5	2	4	19	3545	2	1007	3704	167	48	32	17	272	1	1	2	1	9
R1V114	4259706	100	100	100	100	100	3669	0	5	2	4	19	3545	2	1007	3704	167	23	53	17	272	2	1	3	1	15
R1V115	4330588	94.95	100	50.29	50.16	100	1537	660	5	3	4	21	3358	2	505	1857	167	6	74	17	270	1	9	1	1	6
R1V116	4363755	100	100	50.29	50.25	100	1537	660	5	3	4	21	3545	2	505	1860	167	54	26	17	272	1	1	1	1	7
R1V117	4396994	100	100	50.29	62.59	100	1537	660	5	3	4	21	3545	2	505	2315	167	44	32	17	272	1	1	2	1	7
R1V118	4430185	100	100	50.29	74.82	100	1537	660	5	3	4	21	3545	2	505	2770	167	50	26	17	270	1	1	1	1	7
R1V119	4463370	99.99	100	50.29	87.14	100	1537	660	5	3	4	21	3544	2	505	3227	167	40	36	17	272	3	1	1	1	7
R1V120	4496591	100	100	50.29	99.34	100	1537	660	5	3	4	21	3545	2	505	3679	167	48	37	17	272	1	1	2	1	7
R1V121	4529785	100	100	50.29	86.26	100	1537	275	5	3	4	20	3545	2	505	3195	167	65	20	17	270	2	1	0	1	8
R1V122	4562990	100	100	50.29	98.56	100	1537	275	5	3	4	20	3545	2	505	3650	167	32	48	17	270	1	1	3	1	7
R1V123	4586301	100	100	50.29	100	100	1537	167	5	2	4	19	3545	2	505	3704	167	33	94	17	272	11	2	3	1	7
R1V124	4596196	100	100	57.56	100	100	1537	167	5	2	4	19	3545	2	578	3704	167	56	20	17	270	2	1	0	1	10
R1V125	4629357	100	100	81.95	100	100	1537	167	5	2	4	19	3545	2	824	3704	167	50	150	17	272	15	10	1	1	7
R1V126	4654092	100	100	100	100	100	1537	167	5	2	4	19	3545	2	1007	3704	167	9	145	17	272	15	10	1	1	7
R1V127	4695789	100	100	76.15	100	100	1537	0	5	2	4	19	3545	2	766	3704	167	53	70	17	270	14	2	1	1	7
R1V128	4728333	100	100	100	100	100	1537	0	5	2	4	19	3545	2	1007	3704	167	12	160	17	272	17	10	1	1	7
R1V129	5094200	100	100	50.29	86.21	100	678	275	5	2	4	19	3545	2	505	3191	167	28	48	17	270	1	1	3	1	7
R1V130	5127382	100	100	50.29	98.45	100	678	275	5	2	4	19	3545	2	505	3646	167	50	26	17	270	1	1	1	1	7
R1V131	5160561	100	100	57.36	100	100	678	167	5	2	3	18	3545	2	576	3704	167	13	67	17	270	1	6	2	1	7
R1V132	5193795	100	100	81.73	100	100	678	167	5	2	3	18	3545	2	822	3704	167	6	70	17	270	3	3	3	1	7

R1V133	5225109	100	100	100	100	100	678	167	5	2	4	19	3545	2	1007	3704	167	28	84	17	272	16	0	3	1	8
R1V134	5260182	100	100	75.98	100	100	678	0	5	2	3	18	3545	2	764	3704	167	6	74	17	272	4	9	1	1	7
R1V135	5293074	100	100	100	100	100	678	0	5	2	3	18	3545	2	1007	3704	167	20	148	17	272	21	1	3	1	9
R1V136	5691789	100	100	50.29	88.87	100	0	167	5	2	3	18	3545	2	505	3291	167	44	36	17	272	3	1	1	1	7
R1V137	5724964	100	100	52.48	100	100	0	167	5	2	3	18	3545	2	527	3704	167	43	37	17	270	1	0	3	1	7
R1V138	5758164	100	100	76.85	100	100	0	167	5	2	3	18	3545	2	773	3704	167	7	73	17	272	1	6	3	1	7
R1V139	5790537	100	100	100	100	100	0	167	5	2	3	18	3545	2	1007	3704	167	59	31	17	270	2	1	1	1	10
R1V140	5824518	100	100	71.15	100	100	0	0	5	2	3	18	3545	2	715	3704	167	6	164	17	270	24	8	2	1	7
R1V141	5857775	100	100	95.49	100	100	0	0	5	2	3	18	3545	2	961	3704	167	44	36	17	270	3	1	1	1	9
R1V142	5864065	100	100	100	100	100	0	0	5	2	3	18	3545	2	1007	3704	167	41	77	17	270	9	0	3	1	9

Finally Table G.6 displays the analysis of the results obtained from the application of the response model to the third scenario in Veracruz.

Table G.6. Metrics of the efficient points for the response scenario of 2.5 meters in Veracruz

SOL	COST	FILL RATE (%)					SERVICE UNFULFILLMENT		AGENCIES (per period)				PRODUCTS SUPPLIED					MAXIMUM PERSONNEL P/PERIOD				VEHICLES (MAX USED PER PERIOD)				
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	H	TRIPS
R2V1	1774800	80.59	98.97	50.53	50.23	25.24	24684	23259	2	2	2	16	4718	36	849	3114	76	17	55	0	102	3	3	2	0	19
R2V2	1775345	80.51	98.97	50.53	50.16	25.53	24684	23263	2	2	2	12	4718	36	849	3114	77	22	50	0	107	3	4	1	0	20
R2V3	1809289	80.68	98.97	50.53	50.40	60.13	24684	23259	2	2	2	12	4719	36	849	3114	185	21	51	0	106	2	5	1	0	19
R2V4	1847470	80.49	98.97	50.53	50.16	100	24684	23259	2	2	2	12	4718	36	849	3114	307	17	55	0	102	2	2	3	0	19
R2V5	1847477	80.61	98.97	50.53	50.29	100	24684	23259	2	2	2	12	4718	36	849	3114	307	17	55	0	102	3	3	2	0	20
R2V6	1848587	80.66	98.97	50.53	50.28	100	24684	23259	2	2	2	12	4724	36	849	3115	307	22	50	0	107	2	3	2	0	19
R2V7	1853835	80.54	98.97	50.53	50.19	100	24684	23154	3	2	3	13	4718	36	849	3114	307	17	56	0	102	1	3	3	0	20
R2V8	1885066	80.53	98.97	50.53	50.28	100	24684	22539	3	3	3	18	4718	36	849	3114	307	23	49	0	108	3	2	2	0	21
R2V9	1887883	80.63	100	50.53	50.26	100	24684	22539	3	3	3	18	4719	37	849	3115	307	34	38	0	119	3	2	1	0	20
R2V10	1927156	80.74	100	50.53	50.28	100	24684	22059	3	2	3	16	4722	37	849	3115	307	17	55	0	102	3	3	2	0	20
R2V11	1966483	80.61	98.97	50.53	50.33	99.72	24684	21324	3	2	3	15	4718	36	849	3115	306	45	27	0	130	3	2	0	0	20

R2V12	2005794	80.68	98.97	50.53	50.27	100	24684	20724	3	2	3	17	4723	36	849	3114	307	17	55	0	102	3	3	2	0	21
R2V13	2045099	81.06	100	50.53	50.32	100	24684	20244	3	3	3	18	4750	37	849	3115	307	27	45	0	112	2	4	1	0	20
R2V14	2084398	80.63	98.97	50.53	50.33	98.19	24684	19389	3	3	3	18	4718	36	849	3114	302	23	49	0	108	3	2	2	0	20
R2V15	2123698	81.50	100	50.53	50.34	100	24684	19029	3	3	3	18	4772	37	849	3114	307	27	45	0	112	2	4	1	0	20
R2V16	2162969	80.83	98.97	50.53	50.26	100	24684	18294	3	2	3	14	4727	36	849	3114	307	22	50	0	107	3	4	1	0	20
R2V17	2186436	80.65	98.97	50.53	50.30	100	24684	17814	3	3	3	18	4718	36	849	3114	307	17	55	0	102	3	3	2	0	19
R2V18	2202290	80.66	100	50.53	50.28	100	24684	17694	3	2	3	16	4719	37	849	3114	307	22	50	0	107	2	3	2	0	19
R2V19	2237748	80.58	98.97	50.53	50.29	100	24684	17094	3	3	3	18	4718	36	849	3114	307	34	38	0	119	2	1	2	0	19
R2V20	2241581	80.72	100	50.53	50.32	100	24684	17094	3	3	3	18	4725	37	849	3115	307	22	50	0	107	3	4	1	0	20
R2V21	2280895	84.24	100	50.53	50.34	100	24684	17094	3	3	3	18	4948	37	849	3116	307	28	44	0	113	3	3	1	0	19
R2V22	2320179	81.64	100	50.53	50.33	100	24684	16422	3	2	3	17	4782	37	849	3115	307	34	38	0	119	3	2	1	0	19
R2V23	2359495	80.64	98.97	50.53	50.30	97.94	24684	15819	4	2	3	18	4719	36	849	3115	301	22	50	0	107	3	4	1	0	19
R2V24	2398788	80.92	100	50.53	50.21	100	24684	15339	4	3	4	19	4736	37	849	3114	307	22	50	0	107	3	4	1	0	20
R2V25	2438091	82.10	100	50.53	50.25	100	24684	14979	4	3	4	19	4813	37	849	3116	307	17	55	0	102	3	3	2	0	19
R2V26	2477399	81.30	100	50.53	50.29	100	24684	14544	3	3	3	18	4766	37	849	3116	307	17	55	0	102	3	3	2	0	19
R2V27	2516698	80.64	98.97	50.53	50.30	98.98	24684	13824	3	3	3	18	4718	36	849	3116	304	22	50	0	107	3	4	1	0	19
R2V28	2555990	83.85	100	50.53	50.30	100	24684	13824	3	3	3	18	4922	37	849	3114	307	33	39	0	118	2	3	1	0	21
R2V29	2595292	80.70	98.97	50.53	50.30	100	18294	19284	3	2	3	16	4718	36	849	3115	307	17	65	28	120	13	3	2	0	19
R2V30	2634567	80.63	98.97	50.53	50.22	100	18294	18684	3	3	3	18	4725	36	849	3114	307	34	38	28	119	3	2	1	0	19
R2V31	2673900	80.72	100	50.53	50.18	100	18294	18069	3	2	3	16	4725	37	849	3115	307	20	52	28	105	2	7	0	1	20
R2V32	2713198	80.86	100	50.53	50.28	100	18294	17469	3	3	3	18	4732	37	849	3114	307	34	38	28	119	3	2	1	0	19
R2V33	2736411	80.56	100	50.53	50.27	100	18294	17109	3	3	3	18	4718	37	849	3114	307	21	51	28	106	2	4	2	0	20
R2V34	2752499	82.09	100	50.53	50.31	100	18294	17109	3	3	3	18	4809	37	849	3115	307	17	65	28	120	13	3	2	0	19
R2V35	2791798	85.65	100	50.53	50.37	100	18294	17109	3	3	3	18	5032	37	849	3116	307	17	55	28	102	3	3	2	0	19
R2V36	2831086	82.90	100	50.53	50.24	100	18294	16437	3	2	3	17	4866	37	849	3115	307	17	55	28	102	3	3	2	0	19
R2V37	2870394	81.00	100	50.53	50.32	100	17963	15969	4	3	4	19	4742	37	849	3115	307	44	50	33	129	3	4	1	0	19
R2V38	2909658	80.68	98.97	50.53	50.25	100	17963	15369	4	2	3	18	4724	36	849	3115	307	22	61	33	107	3	4	2	0	20
R2V39	2948954	83.44	100	50.53	50.32	100	17963	15249	4	3	4	19	4897	37	849	3115	307	17	85	33	102	4	9	1	0	21

R2V40	2988282	80.79	100	50.53	50.31	100	17963	14577	4	2	3	18	4731	37	849	3115	307	33	118	33	133	18	4	0	1	20
R2V41	3027584	81.65	100	50.53	50.31	100	18294	13839	3	3	3	18	4782	37	849	3116	307	22	50	28	107	3	4	1	0	19
R2V42	3066877	80.65	100	50.53	50.25	100	17963	13614	4	3	4	19	4720	37	849	3115	307	22	65	33	107	5	3	2	0	20
R2V43	3106198	81.29	100	50.53	50.28	100	17963	13134	5	3	4	20	4762	37	849	3116	307	26	71	33	111	6	5	1	0	19
R2V44	3145489	80.72	98.97	50.53	50.21	100	17963	12699	4	3	4	19	4730	36	849	3114	307	48	44	33	133	2	2	2	0	20
R2V45	3184788	80.62	100	50.53	50.28	100	17963	12219	4	2	3	17	4719	37	849	3114	307	37	66	33	122	3	3	3	0	20
R2V46	3224088	83.03	100	50.53	50.21	100	17963	11979	4	3	4	19	4871	37	849	3114	307	22	65	33	107	4	2	3	0	20
R2V47	3263400	80.69	100	50.53	50.23	100	11573	17559	4	3	4	19	4727	37	849	3115	307	21	65	33	106	5	3	2	0	19
R2V48	3302682	80.50	98.97	50.53	50.20	98.58	11573	16959	4	2	3	18	4718	36	849	3115	302	56	97	33	162	14	2	1	1	20
R2V49	3341992	80.72	98.97	50.53	50.27	100	11573	16344	4	2	3	16	4724	36	849	3115	307	31	65	33	130	13	3	2	0	19
R2V50	3381292	80.56	100	50.53	50.22	99.87	11573	15744	4	2	3	18	4718	37	849	3114	306	33	60	33	118	2	4	2	1	19
R2V51	3413470	80.50	100	50.53	50.21	100	11573	15264	4	3	4	19	4718	37	849	3114	307	17	131	33	136	14	4	3	1	22
R2V52	3420592	81.20	100	50.53	50.17	100	11573	15264	4	3	4	19	4758	37	849	3115	307	44	69	33	129	13	2	1	1	21
R2V53	3459895	84.66	100	50.53	50.18	100	11573	15264	4	3	4	19	4981	37	849	3115	307	39	55	33	124	3	3	2	0	21
R2V54	3499181	82.14	100	50.53	50.27	100	11573	14592	4	2	3	18	4815	37	849	3115	307	44	49	33	147	4	3	1	0	19
R2V55	3538483	80.69	100	50.53	50.25	100	11573	13989	5	2	4	19	4727	37	849	3114	307	37	65	33	122	4	5	1	1	19
R2V56	3577791	81.38	100	50.53	50.27	100	11573	13509	5	3	4	20	4769	37	849	3114	307	42	59	33	127	6	3	1	0	20
R2V57	3617099	82.68	100	50.53	50.36	100	11573	13149	5	3	4	20	4846	37	849	3116	307	19	90	33	105	7	3	3	1	19
R2V58	3656394	80.68	100	50.53	50.33	100	11573	12594	4	2	3	17	4725	37	849	3115	307	36	60	33	121	4	3	2	0	19
R2V59	3695684	80.81	100	50.53	50.23	100	11573	11994	4	3	4	19	4731	37	849	3116	307	37	67	33	122	4	6	1	0	19
R2V60	3734998	80.62	98.97	50.53	50.35	100	11573	11634	5	2	4	19	4719	36	849	3116	307	52	99	33	137	13	2	2	0	20
R2V61	3774248	80.75	98.97	50.53	50.26	100	11573	11034	5	3	4	21	4726	36	849	3114	307	50	32	33	135	3	1	1	1	20
R2V62	3813591	84.06	100	50.53	50.30	100	11573	11034	5	3	4	21	4935	37	849	3114	307	18	131	33	166	12	10	1	0	19
R2V63	3852899	80.88	100	50.53	50.22	100	11573	10239	4	3	4	20	4742	37	849	3115	307	68	33	33	153	3	3	0	0	20
R2V64	3892191	82.15	100	50.53	50.27	100	11573	9879	4	3	4	20	4820	37	849	3114	307	42	65	33	127	13	3	1	0	20
R2V65	3931500	80.66	100	50.53	50.28	100	11573	9447	4	2	3	17	4725	37	849	3114	307	18	76	33	103	5	3	3	0	20
R2V66	3970777	83.03	100	50.53	50.26	100	11573	9207	4	2	4	19	4877	37	849	3114	307	20	77	33	105	6	6	1	0	19
R2V67	4010099	81.18	100	50.53	50.36	100	11573	8484	5	3	4	21	4753	37	849	3114	307	20	74	33	105	2	7	2	0	19

R2V68	4049387	80.54	100	50.53	50.18	100	11573	7884	5	2	4	20	4720	37	849	3115	307	34	71	33	119	4	3	3	0	20
R2V69	4055225	80.57	100	50.53	50.25	100	11573	7764	5	3	4	21	4718	37	849	3114	307	23	78	33	108	3	5	3	1	20
R2V70	4088649	83.57	100	50.53	50.21	100	11573	7764	5	3	4	21	4908	37	849	3114	307	18	70	33	103	5	2	3	0	20
R2V71	4127990	80.98	100	50.53	50.32	100	11573	7092	5	2	4	20	4742	37	849	3114	307	22	66	33	107	3	3	3	0	19
R2V72	4167250	84.57	100	50.53	50.23	100	11573	7092	5	2	4	20	4965	37	849	3114	307	24	75	33	109	6	2	3	0	20
R2V73	4206597	87.96	100	50.53	50.32	100	11573	7092	5	2	4	20	5188	37	849	3115	307	54	49	33	139	3	2	2	0	19
R2V74	4245900	80.62	100	50.53	50.27	100	6137	11409	5	3	4	21	4718	37	849	3114	307	58	33	33	143	3	3	0	0	21
R2V75	4285197	81.85	100	50.53	50.28	100	6137	11049	5	3	4	21	4795	37	849	3115	307	19	88	33	104	5	8	1	1	21
R2V76	4324498	85.40	100	50.53	50.32	100	6137	11049	5	3	4	21	5019	37	849	3114	307	17	84	33	102	4	7	2	0	19
R2V77	4363774	82.68	100	50.53	50.22	100	6137	10377	5	2	4	20	4852	37	849	3115	307	57	49	33	142	4	3	1	0	21
R2V78	4403069	80.68	100	50.53	50.28	100	6137	9654	5	3	4	22	4728	37	849	3115	307	69	37	33	154	4	1	1	0	19
R2V79	4442390	80.61	98.97	50.53	50.25	98.15	6137	9054	5	2	4	21	4719	36	849	3115	302	28	66	33	113	4	4	2	0	21
R2V80	4452495	80.56	100	50.53	50.23	100	6137	8934	5	3	4	22	4718	37	849	3114	307	32	71	33	117	2	4	3	1	19
R2V81	4481692	83.23	100	50.53	50.30	100	6137	8934	5	3	4	22	4883	37	849	3116	307	39	54	33	124	4	2	2	0	20
R2V82	4520990	80.62	100	50.53	50.30	99.65	6137	8262	5	2	4	21	4719	37	849	3115	306	32	61	33	117	3	4	2	0	19
R2V83	4560279	84.13	100	50.53	50.27	100	6137	8262	5	2	4	21	4940	37	849	3116	307	42	69	33	127	8	3	1	0	19
R2V84	4599594	87.51	100	50.53	50.24	100	6137	8262	5	2	4	21	5164	37	849	3114	307	27	71	33	112	5	4	2	0	20
R2V85	4638881	81.55	100	50.53	50.21	100	6137	7362	6	2	4	22	4784	37	849	3115	307	17	90	33	102	4	11	0	1	20
R2V86	4678191	85.02	100	50.53	50.25	100	6137	7362	5	2	4	22	5007	37	849	3115	307	26	61	33	111	4	5	1	0	22
R2V87	4717496	80.56	98.97	50.53	50.26	100	6137	6413	4	2	4	20	4719	36	849	3116	307	71	65	33	156	13	1	3	0	19
R2V88	4756788	83.26	100	50.53	50.25	100	6137	6293	4	3	4	21	4892	37	849	3116	307	43	134	33	154	20	2	2	0	19
R2V89	4794608	80.55	100	50.53	50.29	100	6137	5621	4	2	4	20	4718	37	849	3114	307	20	143	33	163	10	10	3	0	20
R2V90	4796057	80.66	100	50.53	50.22	100	6137	5621	4	2	4	20	4726	37	849	3115	307	46	93	33	178	13	3	1	1	19
R2V91	4835400	84.12	100	50.53	50.26	100	6137	5621	4	2	4	20	4949	37	849	3116	307	42	49	33	127	4	3	1	1	21
R2V92	4874696	87.66	100	50.53	50.29	100	6137	5621	4	2	4	20	5173	37	849	3114	307	48	77	33	133	5	5	2	0	20
R2V93	4913995	81.75	100	50.53	50.24	100	6137	4721	4	2	4	21	4793	37	849	3115	307	35	161	33	181	23	4	2	0	19
R2V94	4953264	85.20	100	50.53	50.23	100	6137	4721	5	2	4	21	5016	37	849	3115	307	19	60	33	104	4	3	2	0	20
R2V95	4992598	88.73	100	50.53	50.26	100	6137	4721	5	2	4	21	5239	37	849	3116	307	19	60	33	104	4	3	2	0	19

R2V96	5031878	82.76	100	50.53	50.24	100	6137	3821	5	2	4	22	4860	37	849	3114	307	28	71	33	113	5	4	2	1	21
R2V97	5071172	80.78	100	50.53	50.27	100	6137	3311	4	2	4	19	4735	37	849	3115	307	24	74	33	109	6	3	2	1	20
R2V98	5110495	80.57	98.97	50.53	50.22	100	6137	2921	5	2	4	23	4718	36	849	3115	307	43	125	33	150	18	4	1	0	19
R2V99	5149785	83.86	100	50.53	50.30	100	6137	2921	5	2	4	23	4927	37	849	3114	307	59	49	33	147	4	3	1	0	20
R2V100	5189096	81.89	100	50.53	50.19	100	6137	2411	4	2	4	20	4802	37	849	3114	307	22	70	33	107	3	3	3	1	21
R2V101	5228396	85.40	100	50.53	50.19	100	6137	2411	4	2	4	20	5025	37	849	3115	307	22	153	33	263	16	5	5	0	20
R2V102	5267699	88.92	100	50.53	50.28	100	6137	2411	5	2	4	20	5248	37	849	3116	307	35	86	33	124	7	3	3	0	19
R2V103	5280440	80.53	100	50.53	50.26	100	6137	1511	5	2	4	21	4718	37	849	3114	307	19	156	33	161	12	8	4	1	19
R2V104	5306966	82.86	100	50.53	50.26	100	6137	1511	5	2	4	21	4869	37	849	3114	307	35	60	33	130	3	5	1	1	19
R2V105	5346298	86.43	100	50.53	50.32	100	6137	1511	5	2	4	21	5092	37	849	3115	307	39	50	33	124	3	4	2	0	19
R2V106	5385554	90.01	100	50.53	50.23	100	6137	1511	5	2	4	21	5315	37	849	3115	307	17	160	33	165	24	3	2	0	19
R2V107	5424896	93.47	100	50.53	50.27	100	6137	1511	5	2	4	21	5538	37	849	3116	307	45	132	33	287	21	2	1	1	21
R2V108	5464199	97.06	100	50.53	50.27	100	6137	1511	5	2	4	21	5762	37	849	3114	307	17	155	33	218	18	9	1	0	20
R2V109	5495048	99.83	100	50.53	50.31	100	6137	1511	5	2	4	21	5937	37	849	3114	307	38	81	33	123	3	3	4	1	20
R2V110	5503500	100	100	50.53	51.68	100	6137	1511	5	2	4	21	5948	37	849	3204	307	17	96	33	111	4	9	2	1	19
R2V111	5542781	100	100	50.53	60.39	100	6137	1511	5	2	4	21	5948	37	849	3742	307	35	150	33	150	23	4	1	0	19
R2V112	5582048	100	100	50.53	51.22	100	6137	971	5	2	4	22	5948	37	849	3177	307	17	83	33	134	2	6	3	1	19
R2V113	5621396	100	100	50.53	59.88	100	6137	971	5	2	4	22	5948	37	849	3716	307	21	73	33	152	6	7	2	0	19
R2V114	5660690	100	100	50.53	68.49	100	6137	971	5	2	4	22	5948	37	849	4254	307	35	81	33	120	3	3	4	1	19
R2V115	5699996	82.47	100	50.53	50.28	100	2571	2235	5	2	4	22	4844	37	849	3116	307	17	111	33	125	4	9	3	1	19
R2V116	5739280	80.52	100	50.53	50.22	100	2571	1725	4	2	4	19	4720	37	849	3114	307	25	72	33	137	3	4	3	0	19
R2V117	5778540	84.00	100	50.53	50.28	100	2571	1725	4	2	4	19	4943	37	849	3114	307	36	97	33	121	4	3	5	1	19
R2V118	5817867	87.59	100	50.53	50.24	100	2571	1725	4	2	4	19	5166	37	849	3115	307	55	59	33	158	4	4	1	1	19
R2V119	5857198	81.60	100	50.53	50.33	100	2571	825	5	2	4	20	4787	37	849	3114	307	31	69	33	116	5	3	2	1	19
R2V120	5896499	85.12	100	50.53	50.23	100	2571	825	5	2	4	20	5010	37	849	3114	307	22	80	33	113	8	3	2	0	20
R2V121	5935798	88.67	100	50.53	50.23	100	2571	825	5	2	4	20	5233	37	849	3115	307	37	90	33	275	18	5	2	0	19
R2V122	5975082	92.11	100	50.53	50.24	100	2571	825	5	2	4	20	5456	37	849	3115	307	61	60	33	146	4	3	2	0	19
R2V123	6014397	95.74	100	50.53	50.28	100	2571	825	5	2	4	20	5679	37	849	3116	307	35	75	33	128	4	3	3	1	19

R2V124	6053694	99.27	100	50.53	50.24	100	2571	825	5	2	4	20	5903	37	849	3114	307	61	43	33	146	4	2	2	0	19
R2V125	6061644	100	100	50.53	50.25	100	2571	825	5	2	4	20	5948	37	849	3114	307	17	86	33	111	2	12	0	1	20
R2V126	6092949	100	100	50.53	57.09	100	2571	825	5	2	4	20	5948	37	849	3543	307	17	66	33	117	2	5	2	1	19
R2V127	6132294	100	100	50.53	65.70	100	2571	825	5	2	4	20	5948	37	849	4082	307	36	115	33	207	23	5	3	1	19
R2V128	6171593	100	100	50.53	74.44	100	2571	825	5	2	4	20	5948	37	849	4620	307	22	90	33	187	18	3	3	1	19
R2V129	6210899	100	100	50.53	83.03	100	2571	825	5	2	4	20	5948	37	849	5159	307	35	90	33	198	18	4	3	1	19
R2V130	6250175	100	100	50.53	91.64	100	2571	825	5	2	4	20	5948	37	849	5697	307	79	90	33	182	18	3	1	1	19
R2V131	6288007	100	100	50.53	100	100	2571	825	5	2	4	20	5948	37	849	6215	307	38	113	33	338	18	3	3	1	23
R2V132	6289469	100	100	51.18	100	100	2571	825	5	2	4	20	5948	37	860	6215	307	48	115	33	155	14	2	3	0	19
R2V133	6328783	100	100	50.53	91.27	100	2571	377	6	2	4	21	5948	37	849	5671	307	83	44	33	168	3	3	2	0	19
R2V134	6368063	100	100	50.53	99.91	100	2571	377	6	2	4	21	5948	37	849	6209	307	46	54	33	131	3	4	1	1	19
R2V135	6368513	100	100	50.53	100	100	2571	377	6	2	4	21	5948	37	849	6215	307	54	53	33	139	3	2	2	1	20
R2V136	6407361	100	100	50.53	93.51	100	2571	8	6	2	4	20	5948	37	849	5808	307	60	44	33	185	3	3	1	0	20
R2V137	6437071	100	100	50.53	100	100	2571	8	6	2	4	20	5948	37	849	6215	307	66	59	33	151	3	3	2	1	20
R2V138	6446682	100	100	54.75	100	100	2571	8	6	2	4	20	5948	37	920	6215	307	44	90	33	267	18	3	2	1	20
R2V139	6485961	100	100	71.94	100	100	2571	8	6	2	4	20	5948	37	1211	6215	307	17	103	33	123	5	5	4	1	19
R2V140	6525239	100	100	89.06	100	100	2571	8	6	2	4	20	5948	37	1502	6215	307	72	70	33	159	14	2	2	1	21
R2V141	6550505	100	100	100	100	100	2571	8	6	2	4	20	5948	37	1689	6215	307	55	53	33	140	3	8	2	1	22
R2V142	6638644	100	100	100	100	100	2571	0	4	2	3	17	5948	37	1689	6215	307	33	113	33	304	15	3	5	1	41
R2V143	6761085	100	100	50.53	94.90	100	1134	825	5	2	4	20	5948	37	849	5899	307	33	95	33	295	19	3	4	0	19
R2V144	6800391	100	100	50.53	85.82	100	1134	377	6	2	4	21	5948	37	849	5335	307	43	95	33	229	19	8	3	1	19
R2V145	6839678	100	100	50.53	94.50	100	1134	377	6	2	4	21	5948	37	849	5873	307	43	95	33	234	19	2	4	1	20
R2V146	6878921	100	100	56.78	100	100	1134	377	6	2	4	21	5948	37	955	6215	307	42	134	33	349	19	4	1	1	19
R2V147	6918293	100	100	50.53	96.73	100	1134	8	6	2	4	20	5948	37	849	6011	307	60	115	33	254	23	3	1	0	20
R2V148	6957600	100	100	61.29	100	100	1134	8	6	2	4	20	5948	37	1030	6214	307	52	98	33	170	14	4	3	0	20
R2V149	6996900	100	100	78.41	100	100	1134	8	6	2	4	20	5948	37	1321	6215	307	22	95	33	333	19	4	5	0	19
R2V150	7036199	100	100	95.51	100	100	1134	8	6	2	4	20	5948	37	1612	6215	307	46	130	33	342	19	4	2	0	19
R2V151	7046622	100	100	100	100	100	1134	8	6	2	4	20	5948	37	1689	6215	307	55	69	33	140	4	2	3	1	21

R2V152	7139827	100	100	100	100	100	1134	0	4	2	3	18	5948	37	1689	6215	307	57	89	33	147	3	8	4	0	19
R2V153	7311283	100	100	50.53	91.72	100	0	456	5	2	4	19	5948	37	849	5701	307	59	95	33	178	19	5	2	0	20
R2V154	7350557	100	100	51.30	100	100	0	456	5	2	4	19	5948	37	862	6215	307	42	115	33	186	23	3	2	1	19
R2V155	7389898	100	100	50.53	91.29	100	0	8	6	2	4	20	5948	37	849	5675	307	29	115	33	324	23	8	3	0	19
R2V156	7429196	100	100	50.53	99.98	100	0	8	6	2	4	20	5948	37	849	6213	307	55	115	33	272	23	1	4	0	20
R2V157	7468481	100	100	67.64	100	100	0	8	6	2	4	20	5948	37	1139	6215	307	28	92	33	181	14	2	4	1	20
R2V158	7507797	100	100	84.82	100	100	0	8	6	2	4	20	5948	37	1430	6215	307	32	115	33	267	23	8	5	0	23
R2V159	7542740	100	100	100	100	100	0	8	6	2	4	20	5948	37	1689	6215	307	21	153	33	500	20	7	1	0	22
R2V160	7542852	100	100	100	100	100	0	8	6	2	4	20	5948	37	1689	6215	307	32	109	33	186	21	4	4	1	25

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From the Pareto frontier displayed on Figure 6.21, each one of the prospective solutions can be analysed individually. Therefore, Table G.7 includes the main metrics of the solutions obtained for the case of a flood of 0.5 meters in Acapulco.

Table G.7. Metrics of the efficient points for the preparedness scenario of 0.5 meters in Acapulco

SOLUTION	COST	AGENCIES	FILL RATE (%)				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES					SHELTERS (%)
			FOOD	MED	NVH	NVS	SHELTERS	DCs	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	TRIPS	AVG OCCUPANCY
A0ND1	1609919	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	99.97
A0ND2	1613754	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	99.67
A0ND3	1616014	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	99.58
A0ND4	1680405	2	0	0	3.79	14.80	27	0	0	0	100	100	0	0	0	0	0	98.93
A0ND5	1683040	1	0	0	12.39	43.72	14	0	0	0	100	100	0	0	0	0	0	99.56
A0ND6	1685421	1	0	0	12.39	43.38	14	0	0	0	100	100	0	0	0	0	0	99.86
A0ND7	1686716	1	0	0	12.39	43.72	14	0	0	0	100	100	0	0	0	0	0	99.50
A0ND8	1707704	2	0	0	12.39	51.50	27	0	0	0	100	100	0	0	0	0	0	99.10
A0ND9	1731405	2	0	6.29	12.39	46.82	28	1	0	15	100	100	0	0	1	0	2	98.37

A0ND10	1750262	2	0	32.80	12.39	47.85	16	2	0	75	100	100	1	0	0	0	2	99.40
A0ND11	1752887	2	0	33.69	12.39	48.54	14	1	0	80	100	100	1	0	0	0	4	99.46
A0ND12	1763791	2	0	43.42	12.39	48.89	13	1	0	100	100	100	1	0	0	0	5	94.99
A0ND13	1821661	3	0	23.62	16.53	55.77	21	1	0	60	100	100	1	0	0	0	6	95.36
A0ND14	1825413	3	0	32.75	16.53	55.68	26	1	0	80	100	100	1	0	0	0	8	97.49
A0ND15	1896990	3	39.29	45.90	12.39	51.64	10	2	17.12	100	100	100	0	4	1	0	4	96.13
A0ND16	2022638	4	79.66	40.92	16.25	54.30	26	3	34.76	100	100	100	0	5	1	1	22	98.32
A0ND17	2028284	4	91.07	39.80	16.13	56.32	18	3	39.76	90	100	100	0	5	1	0	18	98.30
A0ND18	2044669	4	96.17	45.90	16.53	53.66	18	3	42.04	100	100	100	0	4	2	0	18	98.26
A0ND19	2100249	4	0	74.43	44.89	51.41	17	2	0	97.14	100	100	2	0	0	1	8	85.93
A0ND20	2113086	5	39.84	76.18	44.53	56.81	16	2	17.36	100	100	100	0	3	2	1	12	99.40
A0ND21	2214811	5	50.06	64.65	44.48	55.66	29	2	21.88	88.57	100	100	1	5	1	0	23	92.48
A0ND22	2227156	5	89.81	75.58	42.28	55.89	17	2	39.2	100	100	100	0	3	2	2	15	98.79
A0ND23	2232686	5	91.60	77.74	45.44	58.53	15	2	40	100	100	100	0	4	1	0	18	95.94
A0ND24	2241542	5	99.22	77.16	45.44	58.53	13	1	43.32	100	100	100	0	5	1	0	13	97.89
A0ND25	2298894	5	97.34	76.15	45.35	58.21	13	2	42.48	97.14	100	100	0	4	1	0	12	92.24
A0ND26	2478913	5	92.47	80.15	45.44	58.53	15	2	40.32	100	100	100	0	4	0	0	14	84.04
A0ND27	2685848	5	96.67	73.74	44.57	100	15	2	42.24	100	86.78	100	1	1	3	4	16	84.85
A0ND28	2833125	5	97.77	75.76	44.76	99.43	16	3	42.8	100	100	100	1	3	3	2	20	89.69
A0ND29	2905334	4	96.12	77.25	41.31	100	13	4	41.96	100	99.02	100	20	3	3	0	19	80.08
A0ND30	2957798	5	97.52	75.95	44.76	99.20	16	6	42.64	100	98.89	100	1	3	19	0	19	80.01
A0ND31	3111924	5	98.26	75.37	45.44	97.70	13	1	42.88	100	97.63	100	1	1	3	0	13	68.14
A0ND32	3173216	5	99.82	72.64	43.59	99.66	14	3	43.64	97.14	100	100	2	3	1	0	24	64.53
A0ND33	3409597	5	97.84	76.08	44.53	98.69	14	4	42.68	100	97.02	100	2	2	3	1	16	57.40
A0ND34	3755333	5	97.61	73.70	45.42	98.53	21	6	42.72	100	94.46	100	4	11	4	4	28	61.32
A0ND35	4127440	5	100	73.33	45.44	96.05	20	8	43.88	100	100	100	4	5	6	2	36	52.10
A0ND36	4331316	6	91.23	73.77	44.94	95.02	21	8	39.84	100	100	100	4	4	7	4	34	58.36
A0ND37	4559074	6	93.83	73.74	45.44	98.94	21	6	41.08	100	100	100	3	2	3	2	28	43.89

A0ND38	5642559	4	75.28	100	100	99.98	11	2	32.8	100	80.67	44.17	4	2	2	0	12	99.11
A0ND39	5676228	4	100	100	100	100	10	1	43.6	97.78	45.74	36.67	1	1	3	0	10	100

Similarly, Table G.8 contains the metrics for the 62 solutions obtained from the preparedness model applied to Acapulco with a flood depth of 1.5 meters

Table G.8. Metrics of the efficient points for the preparedness scenario of 1.5 meters in Acapulco

SOLUTION	**COST**	**AGENCIES**	**FILL RATE (%)**				**FACILITIES**		**USE RELIEF ITEMS (%)**		**USE HUMAN RESOURCES (%)**		**VEHICLES**					**SHELTERS (%)**	**EVACUATION**
			FOOD	MED	NVH	NVS	SHELTERS	DCS	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	TRIPS	AVG OCCUPANCY	DISTANCE P/P (miles)
A1ND1	4830802	0	0.00	0.00	0.00	0.00	54	0	0.00	0.00	0.00	0.00	0	0	0	0	0	1.00	9.59
A1ND2	4840590	0	0.00	0.00	0.00	0.00	52	0	0.00	0.00	0.00	0.00	0	0	0	0	0	1.00	8.99
A1ND3	4855157	1	0.00	0.00	0.00	2.58	47	0	0.00	0.00	100	0.00	0	0	0	0	0	0.99	9.31
A1ND4	4881210	1	0.00	0.00	0.00	2.64	54	0	0.00	0.00	100	0.00	0	0	0	0	0	0.99	9.65
A1ND5	4905554	1	0.00	0.00	4.13	14.58	51	0	0.00	0.00	100	100	0	0	0	0	0	1.00	9.53
A1ND6	4912402	1	0.00	0.00	4.13	14.56	45	0	0.00	0.00	100	100	0	0	0	0	0	1.00	9.06
A1ND7	4943322	2	0.00	0.00	4.13	17.23	44	0	0.00	0.00	100	100	0	0	0	0	0	0.99	9.79
A1ND8	4985456	3	0.00	6.89	5.51	18.60	54	1	0.00	45.00	100	100	1	0	0	0	8	1.00	9.45
A1ND9	4993207	2	0.00	12.62	4.13	16.31	41	1	0.00	85.00	100	100	1	0	0	0	8	0.99	9.74
A1ND10	5007384	3	0.00	10.72	5.51	17.57	44	2	0.00	70.00	100	100	2	0	0	0	10	1.00	9.60
A1ND11	5034452	3	0.00	14.54	5.31	18.60	57	1	0.00	95.00	100	100	1	0	0	0	8	0.99	10.15
A1ND12	5041197	3	0.00	15.31	5.51	18.60	38	1	0.00	100	100	100	1	0	0	0	6	0.99	9.40
A1ND13	5170025	4	0.00	9.95	15.16	18.03	37	1	0.00	37.14	100	100	1	0	0	0	5	0.99	9.63
A1ND14	5218554	1	0.00	0.00	0.00	44.90	58	0	0.00	0.00	100	0.00	0	0	0	0	0	0.99	9.07
A1ND15	5281274	2	0.00	0.00	0.00	47.54	44	0	0.00	0.00	100	0.00	0	0	0	0	0	0.98	9.62
A1ND16	5395746	4	0.00	14.51	5.28	63.50	35	1	0.00	100	100	100	1	0	0	0	5	0.99	10.00
A1ND17	5436145	4	0.00	14.79	5.28	63.50	33	1	0.00	100	100	100	1	0	0	0	3	0.98	9.50
A1ND18	5513181	4	0.00	22.14	13.32	61.09	37	1	0.00	82.86	100	100	1	0	0	0	8	1.00	9.88
A1ND19	5571037	5	0.00	24.68	15.01	61.48	36	1	0.00	94.29	100	100	1	0	0	1	6	1.00	10.00
A1ND20	5685153	5	8.34	15.17	5.37	64.10	38	2	11.08	100	100	100	0	2	2	0	6	0.93	10.22

A1ND21	5742118	6	10.87	26.15	15.16	64.22	44	2	14.20	100	100	100	0	3	1	0	13	0.98	9.94
A1ND22	5883014	5	66.30	13.77	5.51	62.07	44	2	86.68	100	100	100	1	4	2	0	28	0.97	10.32
A1ND23	5970197	6	53.66	26.78	15.16	64.04	35	2	70.12	100	100	100	0	4	1	0	17	0.99	9.88
A1ND24	6027323	6	63.00	26.27	14.93	64.36	33	1	82.32	100	100	100	0	5	1	0	16	0.99	10.02
A1ND25	6122501	6	75.34	23.40	15.05	59.49	48	4	98.52	100	100	100	3	5	2	1	36	0.97	9.02
A1ND26	6171334	6	65.66	23.84	15.05	61.09	40	3	85.80	94.29	100	100	2	3	3	1	24	0.95	10.25
A1ND27	6198314	6	52.82	26.73	15.16	64.38	34	1	69.04	100	100	100	0	5	1	0	16	0.91	10.13
A1ND28	6199464	6	74.29	25.72	15.16	63.58	34	1	97.12	100	99.68	100	1	5	1	0	21	0.96	9.99
A1ND29	6253531	6	76.22	25.61	15.16	61.90	43	3	99.56	100	100	100	2	4	2	0	30	0.94	10.55
A1ND30	6275182	6	76.22	26.20	15.16	63.60	41	2	99.56	100	100	100	1	3	2	0	24	0.92	10.29
A1ND31	6368319	5	41.91	25.33	13.78	97.03	36	2	54.88	100	100	100	1	4	8	0	27	0.98	9.03
A1ND32	6483614	6	49.46	25.51	15.01	95.93	35	2	64.64	100	100	100	2	1	6	0	29	0.98	9.82
A1ND33	6704384	5	71.78	26.04	13.67	94.73	43	3	93.88	100	100	100	3	4	6	0	38	0.94	9.74
A1ND34	6768704	5	73.71	26.80	13.63	97.64	35	3	96.32	100	100	100	3	2	5	0	28	0.93	9.48
A1ND35	6873782	6	73.52	26.80	15.16	93.74	44	4	96.08	100	100	100	3	5	9	3	50	0.92	9.85
A1ND36	6993918	6	76.52	26.51	15.16	96.85	40	4	100	100	100	100	3	4	6	1	44	0.86	9.83
A1ND37	7231777	7	74.18	25.36	15.16	96.36	49	4	96.96	100	100	100	4	4	5	1	43	0.85	10.18
A1ND38	7490608	7	75.29	25.98	15.16	92.46	49	4	98.40	100	100	100	3	4	5	2	38	0.79	10.23
A1ND39	7738206	7	74.16	24.70	15.10	94.46	47	5	97.00	94.29	100	100	2	5	4	2	40	0.77	9.89
A1ND40	8023455	7	73.24	24.81	15.06	91.27	56	7	95.92	100	100	100	4	5	4	2	50	0.80	8.75
A1ND41	8080471	8	75.71	26.80	15.16	90.15	45	3	98.92	100	100	100	3	1	3	2	28	0.72	10.01
A1ND42	8422173	2	0.00	3.06	100	93.22	34	1	0.00	13.33	98.60	88.94	6	0	0	0	4	0.99	10.52
A1ND43	8615601	3	2.60	6.89	100	93.14	42	2	3.44	30.00	94.43	73.45	3	1	2	0	12	0.96	9.48
A1ND44	8920077	4	21.18	20.91	97.69	79.67	33	5	27.68	96.67	100	69.30	2	1	1	3	21	0.94	9.65
A1ND45	9050008	4	30.12	8.38	98.84	86.13	36	7	39.56	40.00	100	69.30	3	2	3	1	23	0.91	9.52
A1ND46	9088589	5	76.40	22.89	99.69	94.24	31	5	99.96	100	100	68.42	3	1	3	2	32	0.98	9.72
A1ND47	9359501	4	63.76	20.88	99.42	96.60	36	5	83.28	100	100	71.49	4	2	3	1	33	0.87	10.24
A1ND48	9421809	5	75.85	22.15	98.43	93.46	36	4	99.16	100	100	68.86	3	3	2	3	36	0.88	9.77

A1ND49	9455734	5	75.90	21.47	99.69	97.46	36	4	99.20	96.67	99.91	72.81	3	3	3	2	35	0.87	10.35
A1ND50	9534469	6	75.50	33.64	98.89	94.77	37	5	98.64	100	100	75.21	5	2	2	2	36	0.92	9.57
A1ND51	9777035	5	76.16	21.87	99.92	100	37	4	99.48	100	97.68	78.07	3	3	2	3	36	0.94	9.86
A1ND52	9928689	7	75.46	32.45	99.92	99.92	41	4	98.56	100	88.18	85.95	4	4	5	2	43	0.94	9.57
A1ND53	10022168	6	76.25	33.30	100	99.89	39	3	99.60	100	100	88.43	4	4	3	1	44	0.91	9.97
A1ND54	10061802	6	76.13	33.39	99.94	99.98	42	6	99.44	100	99.81	82.64	4	5	6	4	46	0.91	10.03
A1ND55	10124323	6	76.56	33.74	99.74	98.88	37	4	100	100	97.78	76.45	4	2	3	2	36	0.78	10.34
A1ND56	10503845	7	74.28	34.08	99.55	96.66	38	5	97.04	100	100	69.42	3	2	1	3	31	0.74	9.61
A1ND57	10816988	5	75.18	34.08	99.85	99.90	39	4	98.20	100	98.64	84.58	4	4	3	0	32	0.78	9.40
A1ND58	11553815	7	66.61	33.69	99.46	99.77	50	3	87.00	100	99.31	73.14	4	4	5	1	46	0.70	9.45
A1ND59	11839102	8	75.67	32.70	99.61	99.38	45	4	98.84	100	96.92	76.45	3	4	5	2	39	0.67	9.38
A1ND60	12528834	6	73.68	34.45	99.60	99.56	52	2	96.24	100	96.95	97.08	8	1	4	0	32	0.58	9.94
A1ND61	14180643	9	76.50	32.84	99.91	99.82	79	11	100	100	100	91.32	8	11	13	4	105	0.59	9.00
A1ND62	14379448	9	76.56	34.40	99.92	99.96	83	10	100	100	98.01	97.52	7	9	11	4	101	0.58	9.95

Finally, Table G.9 displays the metrics for the scenario of a flood of 2.5 meters of depth in Acapulco.

Table G.9. Metrics of the efficient points for the preparedness scenario of 2.5 meters in Acapulco

SOLUTION	COST	AGENCIES	FILL RATE (%)				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES					SHELTERS (%)
			FOOD	MED	NVH	NVS	SHELTERS	DCS	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	TRIPS	AVG OCCUPANCY
A2ND1	8057277	0	0.00	0.00	0.00	0.00	73	0	0	0.00	0.00	0	0	0	0	0	0	99.99
A2ND2	8058011	0	0.00	0.00	0.00	0.00	71	0	0	0.00	0.00	0	0	0	0	0	0	99.99
A2ND3	8064861	0	0.00	0.00	0.00	0.00	69	0	0	0.00	0.00	0	0	0	0	0	0	99.85
A2ND4	8070791	0	0.00	0.00	0.00	0.00	70	0	0	0.00	0.00	0	0	0	0	0	0	99.64
A2ND5	8070963	0	0.00	0.00	0.00	0.00	68	0	0	0.00	0.00	0	0	0	0	0	0	99.68
A2ND6	8079208	1	0.00	0.00	0.00	1.45	67	0	0	0.00	100	0	0	0	0	0	0	99.93
A2ND7	8096045	1	0.00	0.00	0.00	1.58	72	0	0	0.00	100	0	0	0	0	0	0	99.61
A2ND8	8125946	1	0.00	0.00	2.20	8.75	67	0	0	0.00	100	100	0	0	0	0	0	99.98

A2ND9	8127138	1	0.00	0.00	2.48	8.75	67	0	0	0.00	100	100	0	0	0	0	0	99.97
A2ND10	8130916	1	0.00	0.00	2.48	8.75	65	0	0	0.00	100	100	0	0	0	0	0	99.92
A2ND11	8176948	2	0.00	2.76	2.48	8.47	68	2	0	30.00	100	100	1	0	1	0	6	99.64
A2ND12	8188202	2	0.00	4.13	2.48	9.78	74	1	0	45.00	100	100	1	0	0	0	8	99.34
A2ND13	8256426	3	0.00	4.13	3.31	10.82	68	1	0	45.00	100	100	1	0	0	0	8	99.06
A2ND14	8296073	3	0.00	9.19	3.31	10.82	67	1	0	100	100	100	2	0	0	0	13	99.16
A2ND15	8382227	3	0.00	8.27	3.31	10.82	69	1	0	95.00	100	100	2	0	0	0	16	98.08
A2ND16	8410770	3	0.00	9.19	3.31	10.40	71	2	0	100	100	100	2	0	0	1	17	97.38
A2ND17	8465168	2	0.00	0.00	0.00	28.52	66	0	0	0.00	100	0	0	0	0	0	0	99.55
A2ND18	8497484	2	0.00	0.00	2.48	35.69	73	0	0	0.00	100	100	0	0	0	0	0	99.72
A2ND19	8536440	3	0.00	0.46	2.48	36.72	74	1	0	5.00	100	100	1	0	0	0	1	99.30
A2ND20	8545231	3	0.00	4.59	2.48	36.72	65	1	0	50.00	100	100	1	0	0	0	8	99.55
A2ND21	8562639	3	0.00	9.19	2.48	36.70	64	1	0	100	100	100	1	0	0	0	5	99.76
A2ND22	8566161	3	0.00	9.19	2.48	36.72	69	1	0	100	100	100	1	0	0	0	6	99.81
A2ND23	8568777	3	0.00	9.19	2.48	36.72	63	1	0	100	100	100	1	0	0	0	5	99.57
A2ND24	8581770	3	0.00	9.15	2.48	36.65	71	1	0	100	100	100	1	0	0	0	8	99.36
A2ND25	8626965	3	0.00	8.38	2.48	36.72	77	1	0	95.00	100	100	1	0	0	0	5	98.79
A2ND26	8628950	4	0.00	8.69	3.31	38.10	65	1	0	95.00	100	100	1	0	0	0	6	98.86
A2ND27	8645912	4	0.00	8.58	3.31	38.10	69	1	0	100	100	100	1	0	0	0	7	99.34
A2ND28	8703430	4	0.00	8.73	3.31	38.05	66	1	0	100	100	100	1	0	0	0	8	98.38
A2ND29	8750772	4	0.00	8.04	3.24	38.10	70	1	0	95.00	100	100	1	0	0	0	8	97.77
A2ND30	8791325	4	0.00	8.54	3.31	38.10	69	1	0	100	100	100	1	0	0	0	7	97.07
A2ND31	8873860	5	15.87	8.74	3.31	38.26	74	1	34.6	100	100	100	1	2	2	0	18	98.02
A2ND32	8912704	5	13.04	8.41	3.31	38.65	67	1	28.4	95.00	100	100	0	5	0	0	13	97.76
A2ND33	8955688	6	4.98	15.45	9.09	38.65	66	1	10.84	100	100	100	0	3	0	0	12	98.53
A2ND34	8996296	5	28.10	8.89	3.17	38.65	72	2	61.2	100	100	100	0	4	1	0	15	98.10
A2ND35	9036294	3	0.00	0.00	2.48	63.89	67	0	0	0.00	100	100	0	0	0	0	0	99.53
A2ND36	9077344	4	0.00	0.55	2.48	65.10	77	1	0	10.00	100	100	0	0	1	0	2	99.09

A2ND37	9117099	4	0.00	7.60	2.48	65.06	69	1	0	85.00	100	100	1	1	0	0	6	99.26
A2ND38	9157854	5	0.00	8.41	3.31	66.89	69	1	0	95.00	100	100	1	0	0	0	4	99.29
A2ND39	9171724	5	0.00	9.19	3.31	66.89	63	1	0	100	100	100	1	0	0	0	5	99.27
A2ND40	9241104	4	0.00	8.73	2.48	65.52	67	1	0	95.00	100	100	1	0	0	0	6	97.78
A2ND41	9281393	5	0.00	11.02	8.27	65.52	69	1	0	68.57	100	100	1	0	0	0	7	99.35
A2ND42	9323436	5	0.00	13.03	8.27	65.49	69	1	0	82.86	100	100	1	0	0	0	8	98.78
A2ND43	9364469	5	0.00	13.86	8.27	65.21	70	2	0	91.43	100	100	1	0	0	0	6	98.41
A2ND44	9380533	6	0.00	15.17	8.96	66.85	72	1	0	100	100	100	1	0	0	0	6	98.89
A2ND45	9446301	6	16.75	9.19	3.31	67.45	65	1	36.48	100	100	100	0	5	1	0	8	98.52
A2ND46	9528046	7	8.18	15.68	9.09	66.34	70	2	17.8	100	100	100	0	3	1	0	12	98.62
A2ND47	9557965	6	31.42	8.87	3.31	66.28	71	2	68.44	100	100	100	0	4	2	0	19	98.45
A2ND48	9600913	6	38.91	8.21	3.31	65.53	76	4	84.8	100	100	100	3	4	1	0	30	98.74
A2ND49	9650657	7	24.47	11.48	8.98	66.59	70	1	53.28	74.29	100	100	0	5	2	0	20	98.86
A2ND50	9771568	7	36.26	13.54	9.03	66.38	74	1	79	85.71	100	100	1	6	1	0	26	98.42
A2ND51	9806247	7	44.08	14.72	9.09	63.46	77	2	96	100	100	100	2	8	3	1	45	99.64
A2ND52	9887433	7	34.29	14.86	9.09	64.79	75	3	74.68	100	100	100	1	5	3	1	33	96.93
A2ND53	9977275	7	36.78	14.78	9.09	66.46	72	2	80.12	97.14	99.81	100	1	2	2	0	19	95.58
A2ND54	10056629	7	41.02	15.33	9.09	65.09	68	3	89.4	100	100	100	2	3	1	0	24	95.63
A2ND55	10140830	7	45.28	15.60	9.08	65.33	69	2	98.72	97.14	100	100	1	5	2	1	33	93.75
A2ND56	10180081	7	40.07	16.07	9.09	66.84	71	2	87.24	100	100	100	0	5	1	0	22	93.23
A2ND57	10425165	6	38.36	15.13	9.09	86.45	66	1	83.52	100	99.93	100	3	3	2	0	40	96.95
A2ND58	10590920	6	28.86	14.65	9.09	86.31	73	2	62.84	97.14	100	100	2	5	1	1	35	92.19
A2ND59	10595975	6	21.31	15.85	8.27	96.59	73	5	46.4	100	100	100	6	5	2	0	47	96.80
A2ND60	10877047	5	44.65	14.42	8.20	96.99	81	3	97.24	100	100	100	6	7	8	0	75	98.52
A2ND61	10954786	7	43.71	14.61	9.09	97.47	73	4	95.2	100	100	100	5	6	10	3	67	98.70
A2ND62	11591538	7	45.93	13.70	9.09	93.35	92	5	100	100	100	100	6	10	17	3	118	91.39
A2ND63	11649763	3	0.00	0.00	91.77	59.62	67	0	0	0.00	100	100	0	0	0	0	0	99.44
A2ND64	11660803	6	42.96	14.89	9.09	99.39	84	3	93.56	97.14	99.77	100	4	2	2	4	36	84.90

A2ND65	11765476	3	0.00	12.78	91.87	58.53	71	2	0	100	100	100	2	0	0	0	6	98.56
A2ND66	11898443	4	0.00	12.13	92.59	59.51	73	2	0	93.33	100	100	1	0	1	0	6	94.62
A2ND67	11978385	3	0.00	0.00	88.60	84.40	75	0	0	0.00	99.93	100	0	0	0	0	0	99.45
A2ND68	12103429	5	0.00	7.63	91.57	86.26	74	1	0	60.00	100	100	1	0	1	0	6	98.97
A2ND69	12301165	6	2.24	9.02	92.46	87.71	71	1	4.88	70.00	100	100	0	2	1	0	9	96.97
A2ND70	12538538	7	4.98	16.55	95.63	85.15	73	4	10.96	46.67	100	99.59	3	3	2	1	21	96.02
A2ND71	12675733	6	38.17	13.01	91.75	75.83	71	6	83.28	100	100	100	5	5	2	3	48	98.31
A2ND72	12797678	7	27.28	9.89	89.79	85.38	76	4	59.52	83.33	100	100	8	3	1	2	43	95.43
A2ND73	12839610	7	9.87	19.25	92.98	84.66	80	2	21.52	100	100	99.59	1	2	2	2	21	90.72
A2ND74	12948675	7	1.49	6.88	95.38	98.81	77	3	3.24	37.78	100	100	2	4	4	2	33	96.93
A2ND75	13002775	8	23.50	19.28	96.41	82.46	72	6	51.2	100	100	99.59	6	4	0	3	54	94.96
A2ND76	13329798	7	37.97	18.20	95.56	75.60	83	4	82.8	100	100	100	4	4	16	1	73	93.74
A2ND77	13357239	7	32.94	19.02	96.02	98.85	72	4	71.72	100	100	100	5	5	15	4	67	96.03
A2ND78	13392990	8	45.32	19.14	96.19	98.38	78	4	98.68	100	100	100	5	8	8	4	79	98.25
A2ND79	13505640	8	45.19	19.30	96.32	99.38	73	5	98.4	100	100	100	6	6	13	2	68	97.35
A2ND80	13532231	7	45.61	20.14	96.08	99.75	77	5	99.32	100	99.64	100	5	7	10	3	76	96.88
A2ND81	13817844	7	45.67	19.79	96.00	96.22	76	5	99.44	100	100	100	7	8	11	3	68	91.85
A2ND82	14166753	8	44.81	19.23	95.43	96.55	86	7	97.56	100	100	100	5	9	11	3	80	88.22
A2ND83	14306829	8	45.56	19.21	96.02	99.48	85	5	99.2	100	100	100	5	6	16	2	72	87.32
A2ND84	14455028	7	44.90	20.29	96.18	99.51	87	4	97.76	100	99.03	100	5	6	11	3	69	85.14
A2ND85	14537699	8	45.87	19.60	95.30	98.95	90	6	99.88	100	100	100	5	9	12	4	79	85.29
A2ND86	15634538	7	45.78	19.44	96.29	99.98	92	7	99.68	100	99.03	100	12	8	5	4	83	84.37

After the application of the preparedness model for the three scenarios in Acapulco, the response model was employed seeking to provide a policy for the deployment of resources during the rest of the flood. Table G.10 displays the results of each one of the points of the Pareto frontier obtained by applying the response model to the first scenario.

Table G.10. Metrics of the efficient points for the response scenario of 0.5 meters in Acapulco

SOL	COST	FILL RATE (%)					SERVICE UNFULFILLMENT		AGENCIES (per period)				PRODUCTS SUPPLIED					MAXIMUM PERSONNEL P/PERIOD				VEHICLES (MAX USED PER PERIOD)				
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	B	TRIPS
R0A1	728638.4	81.1	100	50.94	50.73	26.59	12246	8966	1	1	1	12	1503	6	494	1561	55	5	40	0	20	0	3	2	0	10
R0A2	778883.1	81	100	50.94	50.73	27.05	11706	7406	1	1	1	12	1503	6	494	1561	55	5	40	6	124	0	3	2	0	13
R0A3	791170.6	81.2	100	50.94	50.92	54.09	11706	7406	1	1	1	12	1504	6	494	1562	94	4	41	6	124	0	5	1	0	10
R0A4	853371.1	81.4	100	50.94	50.97	40.68	11166	5501	2	1	2	13	1503	6	494	1562	76	5	40	6	127	0	3	2	0	10
R0A5	889169	81.0	100	50.94	50.74	100	11166	5501	2	1	2	13	1503	6	494	1561	190	16	29	6	127	0	3	1	0	11
R0A6	907229.3	81	100	50.94	50.71	100	11166	5231	3	1	2	14	1503	6	494	1561	190	5	45	6	145	1	3	2	0	12
R0A7	915581.3	81.2	100	50.94	50.87	63.78	10626	4736	2	1	2	13	1503	6	494	1561	115	16	29	6	127	0	3	1	0	10
R0A8	939168.8	81.1	100	50.94	50.69	100	10626	4736	2	1	2	13	1503	6	494	1561	190	5	40	6	127	0	3	2	0	10
R0A9	975226.5	81.1	100	50.94	50.70	100	10626	4046	3	1	2	15	1503	6	494	1561	190	4	41	6	150	0	5	1	0	11
R0A10	977769.1	81.7	100	50.94	50.91	100	10626	4046	3	1	2	15	1517	6	494	1562	190	4	41	6	150	0	5	1	0	10
R0A11	1025244	81.0	100	50.94	50.76	100	10111	3633	3	1	2	15	1503	6	494	1561	190	5	40	6	150	0	3	2	0	11
R0A12	1039981	81.5	100	50.94	50.98	100	9613	3936	2	1	2	13	1507	6	494	1562	190	4	41	6	127	0	5	1	0	10
R0A13	1102186	81.2	100	50.94	50.96	89.06	9119	3211	3	1	2	14	1504	6	494	1562	173	5	40	6	150	0	3	2	0	10
R0A14	1125316	80.8	100	50.94	50.70	100	9119	2866	3	1	2	15	1503	6	494	1561	190	5	40	6	150	0	3	2	0	11
R0A15	1164375	82.4	100	50.94	50.82	100	8640	2859	3	1	2	14	1543	6	494	1562	190	16	29	6	150	0	3	1	0	10
R0A16	1175350	81.1	100	50.94	50.77	100	8640	2514	3	1	2	15	1503	6	494	1561	190	6	39	6	150	0	1	3	0	10
R0A17	1226529	81.3	100	50.94	50.84	100	8180	2186	3	1	2	15	1510	6	494	1561	190	16	29	6	150	0	3	1	0	10
R0A18	1275378	80.9	100	50.94	50.78	100	7727	1868	3	1	2	15	1503	6	494	1561	190	5	40	6	150	0	3	2	0	11
R0A19	1288768	83.6	100	50.94	50.91	100	7727	1868	3	1	2	15	1579	6	494	1562	190	5	40	6	150	0	3	2	0	10
R0A20	1325385	81.0	100	50.94	50.66	100	7294	1578	3	1	2	15	1503	6	494	1561	190	11	34	6	150	0	2	2	0	10
R0A21	1350996	85.9	100	51.04	50.89	100	7294	1578	3	1	2	15	1648	6	495	1561	190	4	41	6	150	0	5	1	0	10
R0A22	1375429	81.0	100	50.94	50.73	100	6886	1323	3	1	2	15	1503	6	494	1561	190	6	39	6	150	0	1	3	0	10
R0A23	1413167	81.2	100	50.94	50.88	97.16	6706	1023	4	1	2	16	1503	6	494	1562	184	16	29	8	170	0	3	1	0	10
R0A24	1414981	80.9	100	50.94	50.72	100	6706	1023	4	1	2	16	1503	6	494	1561	190	5	40	8	170	0	3	2	0	10
R0A25	1454640	80.9	100	50.94	50.69	100	6526	747	4	1	2	17	1503	6	494	1561	190	5	40	8	170	0	3	2	0	10
R0A26	1475388	84.7	100	50.94	50.75	100	6526	747	4	1	2	17	1621	6	494	1561	190	16	29	8	170	0	3	1	0	10

R0A27	1537537	95.8	100	50.94	50.87	100	6526	747	4	1	2	17	1974	6	494	1561	190	16	29	8	170	0	3	1	0	10
R0A28	1599774	81.7	100	50.94	50.82	100	5494	752	5	1	2	19	1529	6	494	1563	190	16	29	22	170	0	3	1	0	10
R0A29	1661995	91.3	100	50.94	51.03	100	5266	747	5	1	2	18	1823	6	494	1564	190	5	40	22	170	0	3	2	0	10
R0A30	1724171	100	100	50.94	56.25	100	5266	747	4	1	2	18	2108	6	494	1728	190	22	23	22	170	0	2	1	0	10
R0A31	1756281	81.1	100	50.94	50.69	100	4006	747	5	1	2	19	1503	6	494	1561	190	11	34	22	170	0	2	2	0	10
R0A32	1786367	86.4	100	50.94	50.87	100	4006	747	5	1	2	19	1674	6	494	1561	190	5	40	22	170	0	3	2	0	10
R0A33	1848589	97.4	100	50.94	50.73	100	4006	747	5	1	2	19	2027	6	494	1562	190	16	29	22	170	0	3	1	0	10
R0A34	1862777	100	100	50.94	50.74	100	4006	747	5	1	2	19	2108	6	494	1561	190	4	41	22	170	0	5	1	0	10
R0A35	1863120	100	100	50.94	50.88	100	4006	747	5	1	2	19	2108	6	494	1565	190	11	34	22	170	0	2	2	0	10
R0A36	1910751	100	100	50.94	71.73	100	4006	747	5	1	2	19	2108	6	494	2218	190	4	41	22	170	0	5	1	0	10
R0A37	1972947	100	100	50.94	98.95	100	4006	747	5	1	2	19	2108	6	494	3070	190	22	23	22	170	0	2	1	0	10
R0A38	1975416	100	100	50.94	100	100	4006	747	5	1	2	19	2108	6	494	3104	190	4	41	22	170	0	5	1	0	10
R0A39	2035191	100	100	50.94	73.48	100	4006	36	6	1	2	20	2108	6	494	2276	190	4	46	22	219	1	5	1	0	10
R0A40	2095622	100	100	50.94	100	100	4006	36	6	1	2	20	2108	6	494	3104	190	28	22	22	225	1	1	1	0	10
R0A41	2097392	100	100	52.26	100	100	4006	36	6	1	2	20	2108	6	507	3104	190	4	46	22	219	1	5	1	0	10
R0A42	2145684	100	100	50.94	100	100	3745	14	6	1	2	20	2108	6	494	3104	190	3	50	22	219	1	2	3	0	10
R0A43	2159559	100	100	61.51	100	100	3745	14	6	1	2	20	2108	6	597	3104	190	5	45	22	222	1	3	2	0	10
R0A44	2185295	100	100	50.94	100	100	3582	14	6	1	2	21	2108	6	494	3104	190	3	50	22	219	1	2	3	0	10
R0A45	2221799	100	100	78.42	100	100	3582	14	6	1	2	21	2108	6	764	3104	190	5	45	22	219	1	3	2	0	11
R0A46	2283985	100	100	95.59	99.97	100	3487	14	6	1	2	22	2108	6	932	3103	190	28	22	22	219	4	1	1	0	11
R0A47	2346159	100	100	88.19	100	100	3220	14	6	1	2	21	2108	6	862	3104	190	4	46	22	222	1	5	1	0	10
R0A48	2361720	100	100	100	100	100	3220	14	6	1	2	21	2108	6	977	3104	190	16	34	22	219	1	3	1	0	10
R0A49	2401411	100	100	100	100	100	3125	14	6	1	2	22	2108	6	977	3104	190	5	45	22	219	4	3	2	0	12
R0A50	2470586	100	100	92.55	100	100	2943	14	6	1	2	24	2108	6	903	3104	190	23	28	22	219	4	2	1	0	10
R0A51	2480601	100	100	100	100	100	2943	14	6	1	2	24	2108	6	977	3104	190	22	28	22	219	4	2	1	0	11
R0A52	2520214	100	100	100	100	100	2857	14	6	1	3	25	2108	6	977	3104	190	4	46	22	219	4	5	1	0	10
R0A53	2520250	100	100	100	100	100	2857	14	6	1	3	25	2108	6	977	3104	190	4	46	22	220	4	5	1	0	11
R0A54	2594983	100	100	96.60	100	100	2691	14	6	1	3	27	2108	6	943	3104	190	22	28	22	225	4	2	1	0	12

R0A55	2599466	100	100	100	100	100	2691	14	6	1	3	27	2108	6	977	3104	190	3	50	22	222	4	2	3	0	10
R0A56	2639105	100	100	100	100	100	2613	14	6	1	3	28	2108	6	977	3104	190	12	44	22	219	4	2	2	0	11
R0A57	2657194	100	100	83.60	100	100	2540	14	6	1	3	29	2108	6	817	3104	190	11	34	22	228	4	2	2	0	12
R0A58	2678720	100	100	100	100	100	2540	14	6	1	3	29	2108	6	977	3104	190	4	46	22	225	4	5	1	0	10
R0A59	2718503	100	100	100	100	100	2513	14	6	2	3	30	2108	6	977	3104	190	31	23	22	219	4	2	1	0	13
R0A60	2781082	100	100	100	100	100	2461	15	6	1	3	30	2115	6	977	3104	190	6	49	22	219	2	1	3	0	21
R0A61	2789937	100	100	100	100	100	2436	14	6	1	3	29	2108	6	977	3104	190	12	44	22	219	4	2	2	0	10
R0A62	2829565	100	100	100	100	100	2409	14	6	2	3	30	2108	6	977	3104	190	17	33	22	225	4	1	2	0	10
R0A63	2901215	100	100	100	100	100	2340	14	6	1	3	29	2108	6	977	3104	190	22	28	22	225	4	2	1	0	12
R0A64	2940773	100	100	100	100	100	2313	14	6	2	3	30	2108	6	977	3104	190	28	27	22	220	4	1	1	0	11
R0A65	3012298	100	100	100	100	100	2244	14	6	1	3	29	2108	6	977	3104	190	22	28	22	219	1	2	1	0	10
R0A66	3092442	100	100	100	100	100	2200	27	6	1	3	32	2108	6	977	3104	190	5	45	22	225	4	3	2	0	12
R0A67	3152842	100	100	100	100	100	2138	15	6	2	3	31	2108	6	977	3104	190	17	33	22	225	4	1	2	0	12
R0A68	3213914	100	100	100	100	100	2091	15	6	1	3	31	2108	6	977	3104	190	22	28	22	219	4	2	1	0	10
R0A69	3224312	100	100	100	100	100	2078	15	6	1	3	30	2108	6	977	3104	190	22	28	22	219	1	2	1	0	10
R0A70	3274402	100	100	100	100	100	2046	14	6	2	3	30	2108	6	977	3104	190	5	40	22	219	0	3	2	0	10
R0A71	3335532	100	100	100	100	100	1994	15	6	1	3	30	2108	6	977	3104	190	22	28	22	225	1	2	1	0	10
R0A72	3403582	100	100	100	100	100	1963	14	6	2	3	31	2108	6	977	3104	190	25	33	22	225	1	1	2	0	10
R0A73	3457196	100	100	100	100	100	1911	14	6	1	3	29	2108	6	977	3104	190	6	39	22	219	0	1	3	0	10
R0A74	3527963	100	100	100	100	100	1894	2	6	2	3	33	2108	6	977	3104	190	45	34	22	230	0	2	2	0	10
R0A75	3547489	100	100	100	100	100	1837	15	6	1	3	31	2108	6	977	3104	190	28	22	22	219	1	1	1	0	10
R0A76	3547502	100	100	100	100	100	1837	15	6	1	3	31	2108	6	977	3104	190	3	50	22	219	1	2	3	0	10
R0A77	3587132	100	100	100	100	100	1810	15	6	2	3	32	2108	6	977	3104	190	3	50	22	219	1	2	3	0	10
R0A78	3587132	100	100	100	100	100	1810	15	6	2	3	32	2108	6	977	3104	190	4	46	22	219	4	5	1	0	10
R0A79	3587135	100	100	100	100	100	1810	15	6	2	3	32	2108	6	977	3104	190	25	28	22	221	1	2	1	0	10
R0A80	3639094	100	100	100	100	100	1810	2	6	2	3	33	2108	6	977	3104	190	45	44	22	220	2	2	2	0	10
R0A81	3708957	100	100	100	100	100	1796	14	6	2	3	31	2108	6	977	3104	190	3	50	22	219	1	2	3	0	13
R0A82	3771173	100	100	100	100	100	1796	1	6	2	3	31	2108	6	977	3104	190	45	39	22	225	1	2	2	0	13

R0A83	3829177	100	100	100	100	100	1796	0	6	2	3	32	2108	6	977	3104	190	6	50	22	219	0	1	4	0	11
R0A84	4703770	100	100	100	100	100	1796	0	6	2	3	36	2108	6	977	3104	190	9	45	22	575	4	2	3	0	16
R0A85	5570660	100	100	100	100	100	1662	14	4	1	2	20	2108	6	977	3104	190	17	38	41	219	2	1	2	0	10
R0A86	5642713	100	100	94.66	100	100	1492	14	4	1	2	22	2108	6	924	3104	190	10	40	41	219	1	4	1	0	11
R0A87	5689522	100	100	100	100	100	1410	14	4	1	2	23	2108	6	977	3104	190	22	93	41	219	14	2	1	0	10
R0A88	5767193	100	100	98.89	100	100	1259	14	4	1	3	25	2108	6	965	3104	190	3	115	41	219	14	2	3	0	12
R0A89	5808488	100	100	100	100	100	1232	14	4	2	3	26	2108	6	977	3104	190	6	115	41	219	14	2	3	0	12
R0A90	5880075	100	100	100	100	100	1155	14	4	1	3	25	2108	6	977	3104	190	31	87	41	219	14	1	1	0	14
R0A91	5919654	100	100	100	100	100	1128	14	4	2	3	26	2108	6	977	3104	190	31	87	41	219	14	1	1	0	12
R0A92	6009442	100	100	100	100	100	1059	14	4	1	3	26	2108	6	977	3104	190	6	55	41	219	2	2	3	0	19
R0A93	6078183	100	100	97.47	100	100	1002	15	4	1	3	27	2108	6	952	3104	190	25	93	41	219	14	2	1	0	10
R0A94	6140387	100	100	98.87	100	100	936	14	4	2	3	26	2108	6	965	3104	190	6	111	41	219	14	5	1	0	11
R0A95	6202597	100	100	99.69	100	100	884	15	4	1	3	26	2108	6	973	3104	190	7	46	41	219	1	5	1	0	10
R0A96	6253545	100	100	100	100	100	849	14	4	2	3	26	2108	6	977	3104	190	6	44	41	219	1	1	3	0	20
R0A97	6325088	100	100	100	100	100	792	14	4	1	3	25	2108	6	977	3104	190	6	109	41	219	14	1	3	0	22
R0A98	6364413	100	100	100	100	100	765	14	4	2	3	26	2108	6	977	3104	190	17	33	41	219	1	1	2	0	10
R0A99	6451393	100	100	97.53	100	100	696	15	4	2	3	28	2108	6	952	3104	190	3	50	41	219	1	2	3	0	10
R0A100	6513530	100	100	98.25	100	100	640	27	4	1	3	28	2108	6	959	3104	190	3	50	41	219	4	2	3	0	11
R0A101	6575715	100	100	99.51	100	100	608	14	4	2	3	27	2108	6	972	3104	190	11	39	41	219	1	2	2	0	10
R0A102	6637731	100	100	100	100	100	556	15	4	1	3	27	2108	6	977	3104	190	3	50	41	219	1	2	3	0	14
R0A103	6677165	100	100	100	100	100	529	15	4	2	3	28	2108	6	977	3104	190	7	111	41	219	14	5	1	0	10
R0A104	6677244	100	100	100	100	100	529	15	4	2	3	28	2108	6	977	3104	190	9	89	41	219	10	1	3	0	10
R0A105	6687724	100	100	100	100	100	529	14	4	2	3	27	2108	6	977	3104	190	9	109	41	219	14	1	3	0	14
R0A106	6729120	100	100	100	100	100	529	2	5	2	3	29	2108	6	977	3104	190	45	115	41	219	14	2	3	0	10
R0A107	6729127	100	100	100	100	100	529	2	5	2	3	29	2108	6	977	3104	190	39	104	41	219	14	2	2	0	10
R0A108	6729192	100	100	100	100	100	529	2	5	2	3	29	2108	6	977	3104	190	4	115	41	219	14	5	3	0	11
R0A109	6739566	100	100	100	100	100	529	1	5	2	3	28	2108	6	977	3104	190	45	100	41	219	11	2	3	0	10
R0A110	6807821	100	100	100	100	100	529	0	4	2	3	28	2108	6	977	3104	190	31	87	41	219	14	1	1	0	11

R0A111	6944796	100	100	100	100	100	515	1	5	2	3	32	2108	6	977	3104	190	39	104	41	219	14	2	2	0	18
R0A112	7005208	100	100	100	100	100	515	0	5	2	3	30	2108	6	977	3104	190	11	39	41	227	1	2	2	0	12
R0A113	9312543	100	100	99.95	100	100	448	0	2	1	2	22	2108	6	976	3104	190	9	109	41	219	14	1	3	0	11
R0A114	9352459	100	100	100	100	100	421	0	2	1	2	23	2108	6	977	3104	190	6	109	41	219	14	1	3	0	15
R0A115	9423901	100	100	100	100	100	361	0	2	1	2	22	2108	6	977	3104	190	3	115	41	219	14	2	3	0	12
R0A116	9463460	100	100	100	100	100	334	0	2	1	2	23	2108	6	977	3104	190	31	87	41	219	14	1	1	0	11
R0A117	9535131	100	100	100	100	100	277	0	2	1	2	22	2108	6	977	3104	190	3	115	41	219	14	2	3	0	10
R0A118	9623579	100	100	98.56	100	100	208	1	3	1	2	24	2108	6	963	3104	190	3	115	41	219	14	2	3	0	10
R0A119	9664436	100	100	100	100	100	194	0	3	1	2	23	2108	6	977	3104	190	15	115	41	219	14	2	3	0	13
R0A120	9747113	100	100	100	100	100	120	0	3	1	2	23	2108	6	977	3104	190	3	115	41	219	14	2	3	0	10
R0A121	9797076	100	100	100	100	100	88	0	2	1	2	23	2108	6	977	3104	190	20	98	41	219	14	1	2	0	10
R0A122	9868683	100	100	100	100	100	41	0	2	1	2	22	2108	6	977	3104	190	3	115	41	219	14	2	3	0	10
R0A123	9887553	100	100	100	100	100	14	1	3	1	3	25	2108	6	977	3104	190	3	115	41	219	14	2	3	0	11
R0A124	9926364	100	100	100	100	100	14	0	3	1	2	24	2108	6	977	3104	190	6	109	41	219	14	1	3	0	11
R0A125	9998662	100	100	100	100	100	0	1	3	1	3	25	2108	6	977	3104	190	31	87	41	219	14	1	1	0	10
R0A126	9998733	100	100	100	100	100	0	0	3	1	3	25	2108	6	977	3104	190	3	115	41	219	14	2	3	0	10

Similarly, Table G.11 shows the metrics for the non-dominated solutions obtained on the application of the response model to the real conditions of the flood of 2013 in Acapulco.

Table G.11. Metrics of the efficient points for the response scenario of 1.5 meters in Acapulco

SOL	**COST**	**FILL RATE (%)**					**SERVICE UNFULFILLMENT**		**AGENCIES (per period)**				**PRODUCTS SUPPLIED**					**MAXIMUM PERSONNEL P/PERIOD**				**VEHICLES (MAX USED PER PERIOD)**				
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MIN	MAX	AVERAGE	TOTAL	FOOD	MEDI	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	B	TRIPS
R1A1	3855340	81.6	99.0	51.4	51.0	27.9	30000	33961	2	5	3	32	5356	112	1494	4720	214	197	65	8	33	2	4	2	3	44
R1A2	4016411	81.7	99.0	51.4	51.2	99.5	29945	34844	2	5	3	32	5356	112	1494	4720	720	197	71	8	27	3	5	2	3	90
R1A3	4142999	81.6	99.0	51.4	51.0	98.4	29493	33926	2	5	4	40	5356	112	1494	4720	702	197	71	8	33	4	5	2	3	79
R1A4	4610913	81.5	99.0	51.4	51.1	99.6	29459	29579	2	4	4	41	5356	112	1494	4729	723	205	77	8	336	2	6	2	3	85

R1A5	4629003	81.6	99.0	51.4	51.1	99.5	29502	29521	2	4	4	42	5356	112	1494	4720	724	198	82	8	331	3	5	3	3	91
R1A6	5013704	81.6	99.0	51.4	51.0	100	30104	20160	3	5	4	41	5356	112	1494	4720	726	197	72	8	364	1	6	2	3	83
R1A7	5151282	81.6	99.0	51.4	51.1	100	29871	19843	3	5	4	46	5356	112	1494	4720	726	200	72	8	364	2	6	2	3	89
R1A8	5287825	81.6	99.0	51.4	51.1	100	30104	17744	3	6	4	45	5356	112	1494	4720	726	197	105	8	463	2	7	4	3	103
R1A9	5418714	81.6	99.0	51.4	51.0	100	29857	16627	3	6	4	48	5356	112	1494	4720	726	199	93	8	441	3	6	3	3	95
R1A10	5459041	81.5	99.0	51.4	51.0	95.0	29801	16191	3	6	4	45	5356	112	1494	4720	698	205	123	8	696	3	5	6	4	98
R1A11	5898190	81.6	100	51.4	51.0	100	29933	9379	3	5	5	51	5356	115	1494	4720	726	198	137	8	657	4	7	6	3	88
R1A12	6035371	81.5	100	51.4	51.0	99.8	29433	8479	3	6	5	55	5356	115	1494	4720	725	197	147	8	680	2	8	7	4	101
R1A13	6215076	81.4	100	51.4	51.0	100	28738	6652	3	6	5	59	5356	115	1494	4720	726	197	153	8	651	2	5	10	3	80
R1A14	6433371	81.5	100	51.4	51.1	100	28738	5287	3	6	5	58	5356	115	1494	4720	726	198	175	8	651	2	5	12	3	89
R1A15	6945685	81.5	100	51.4	51.0	97.0	25078	4887	4	7	6	63	5356	115	1494	4720	692	197	191	22	636	3	4	13	3	91
R1A16	6960044	81.6	100	51.4	51.0	99.0	25078	4376	4	7	6	63	5387	115	1494	4720	721	210	160	22	654	4	3	10	4	90
R1A17	7252063	100	100	51.4	51.0	98.8	25078	4968	4	7	6	62	7156	115	1494	4720	716	197	166	22	638	2	5	12	2	90
R1A18	7333220	100	100	51.4	51.0	100	24930	4459	4	7	6	65	7156	115	1494	4720	726	197	147	22	657	3	4	9	3	87
R1A19	7427285	100	100	51.4	50.9	99.9	25001	3601	4	7	6	64	7156	115	1494	4720	724	199	149	22	653	2	6	9	3	112
R1A20	7724177	100	100	51.4	100	100	24930	4772	4	7	6	66	7156	115	1494	9360	726	199	147	22	678	3	4	9	3	93
R1A21	8439989	100	100	51.4	96.6	100	22793	1747	4	7	6	66	7156	115	1494	9047	726	197	87	22	717	3	5	3	3	86
R1A22	8933665	100	100	51.4	100	100	20514	1746	4	7	6	70	7156	115	1494	9360	725	197	154	22	650	3	2	11	4	82
R1A23	9084314	100	100	51.4	100	100	19838	1604	4	7	6	71	7156	115	1494	9360	726	202	142	22	657	3	5	8	3	81
R1A24	9427323	100	100	51.4	100	100	19108	1085	4	7	6	72	7156	115	1494	9360	726	219	123	22	659	3	5	6	4	82
R1A25	9479802	100	100	51.4	100	100	19108	913	4	7	7	73	7156	115	1494	9360	726	197	147	22	657	3	4	9	3	84
R1A26	9618690	100	100	51.4	100	100	19024	722	4	7	7	74	7156	115	1494	9360	715	333	147	22	657	4	5	8	3	94
R1A27	9671963	100	100	83.5	100	100	18962	876	4	7	7	76	7156	115	2451	9360	726	202	142	22	657	3	5	8	4	83
R1A28	9732398	100	100	100	100	100	19024	794	4	7	7	75	7156	115	2936	9360	726	334	144	22	657	3	9	6	3	99
R1A29	9835009	100	100	100	100	100	19024	552	4	7	7	75	7156	115	2936	9360	726	300	165	22	657	3	7	9	3	108
R1A30	9853029	100	100	100	100	100	19032	426	4	7	7	76	7156	115	2936	9360	726	199	145	22	657	4	12	4	3	105
R1A31	12443980	100	100	64.0	100	100	11315	745	4	7	6	71	7156	115	1873	9360	726	292	168	127	905	3	2	12	3	78
R1A32	12732716	100	100	100	100	100	11167	453	4	7	6	71	7156	115	2936	9360	726	199	116	127	867	2	7	5	3	85

R1A33	12766954	100	100	99.4	100	100	11167	411	4	7	7	73	7156	115	2918	9360	726	215	350	127	666	4	42	6	4	95
R1A34	12948629	100	100	100	100	100	10881	285	4	7	7	73	7156	115	2936	9360	726	527	110	127	657	3	7	4	3	91
R1A35	13001470	100	100	100	100	100	10881	254	4	7	7	74	7156	115	2936	9360	726	499	138	127	657	3	8	6	3	105
R1A36	13599210	100	100	100	100	100	10881	190	4	7	6	71	7156	115	2936	9360	726	374	454	127	663	4	6	37	4	89
R1A37	15701854	100	100	100	100	100	5384	40	1	7	6	67	7156	115	2936	9360	726	290	437	127	660	14	57	6	3	93
R1A38	15724135	100	100	100	100	100	5346	53	1	7	6	67	7156	115	2936	9360	726	201	205	127	892	14	9	12	3	105
R1A39	15741437	100	100	100	100	100	5346	24	1	7	6	68	7156	115	2936	9360	726	199	437	127	657	14	5	35	4	95
R1A40	15839044	100	100	100	100	100	5346	8	1	7	6	66	7156	115	2936	9360	726	225	115	127	750	14	5	6	3	90
R1A41	16770102	100	100	100	100	100	5346	0	1	6	5	51	7156	115	2936	9360	726	286	138	127	790	14	6	8	3	104
R1A42	18747068	100	100	100	100	100	4102	21	1	7	6	63	7156	115	2936	9360	726	215	173	127	876	14	7	9	4	91
R1A43	18953948	100	100	100	100	100	4102	0	1	7	5	54	7156	115	2936	9360	726	361	131	127	965	14	9	5	4	136
R1A44	21878452	100	100	100	100	100	3529	5	1	7	5	52	7156	115	2936	9360	726	387	144	127	906	14	10	5	3	105
R1A45	22907714	100	100	100	100	100	3529	2	1	8	5	56	7156	115	2936	9360	726	583	156	127	657	14	6	9	2	91
R1A46	25461547	100	100	100	100	100	2986	0	1	7	5	53	7156	115	2936	9360	726	416	461	127	657	28	7	35	3	122
R1A47	28333133	100	100	100	100	100	2478	0	1	7	4	47	7156	115	2936	9360	726	419	237	127	657	14	3	17	4	125
R1A48	30500471	100	100	100	100	100	1943	0	1	7	4	43	7156	115	2936	9360	726	208	425	127	663	14	5	33	4	116
R1A49	34034688	100	100	100	100	100	1466	0	1	6	3	33	7156	115	2936	9360	726	391	440	127	657	14	8	33	3	135
R1A50	37037516	100	100	100	100	100	1033	0	1	7	4	37	7156	115	2936	9360	726	561	115	127	893	14	3	6	4	107
R1A51	40009467	100	100	100	100	100	564	0	1	7	3	36	7156	115	2936	9360	726	297	159	127	902	18	3	10	4	125
R1A52	42369934	100	100	100	100	100	173	0	1	6	2	22	7156	115	2936	9360	726	416	215	127	657	14	7	9	3	156
R1A53	46000054	100	100	100	100	99.7	0	0	1	5	3	27	7156	115	2936	9360	726	202	483	127	664	52	22	8	3	159
R1A54	46725583	100	100	100	100	100	0	0	1	5	4	40	7156	115	2936	9360	726	202	137	127	876	16	3	4	3	221

Finally, Table G.12 displays the features of the set of efficient points obtained from the application of the response model to a scenario of a 2.5 meter height flood.

Table G.12. Metrics of the efficient points for the response scenario of 2.5 meters in Acapulco

SOL	**COST**	**FILL RATE (%)**	**SERVICE UNFULFILLMENT**	**AGENCIES (per period)**	**PRODUCTS SUPPLIED**	**MAXIMUM PERSONNEL P/PERIOD**	**MAXIMUM VEHICLES P/PERIOD**	

		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVERAGE	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	B	TRIPS
A2R1	4658644	81.8	98.0	51.5	51.1	27.0	62121	59992	3	1	2	18	10491	229	2496	7808	357	52	206	0	227	6	10	10	2	85
A2R2	4658661	81.8	98.0	51.5	51.1	27.0	61855	59328	3	1	2	14	10491	229	2496	7808	357	45	200	0	256	6	9	10	2	86
A2R3	4658964	81.7	98.0	51.5	51.1	26.9	60391	58002	3	1	2	14	10491	229	2496	7808	357	45	240	2	214	4	10	14	2	86
A2R4	4739428	81.6	98.0	51.5	51.1	26.9	57817	50346	3	1	2	14	10491	229	2496	7808	357	45	239	6	215	4	8	15	2	86
A2R5	4804332	81.8	98.0	51.5	51.2	26.9	55863	46720	3	1	2	14	10491	229	2496	7808	357	34	284	6	170	3	9	19	2	88
A2R6	4838051	81.7	98.0	51.5	51.0	27.4	55249	42684	3	1	2	15	10491	229	2496	7808	357	33	232	6	222	3	9	14	3	87
A2R7	4878546	81.7	98.0	51.5	51.1	27.1	54896	41221	3	1	2	16	10491	229	2496	7808	361	29	180	6	274	3	10	9	2	85
A2R8	4887571	82.0	98.0	51.5	51.3	27.0	54710	40433	3	1	2	15	10491	229	2496	7808	357	37	192	6	262	2	11	10	2	82
A2R9	4961724	81.9	98.0	51.5	51.2	27.8	54171	38382	4	1	2	16	10491	229	2496	7808	375	29	192	8	389	2	11	10	2	86
A2R10	7154016	81.7	100	51.5	51.2	75.5	53199	15135	6	1	4	46	10491	234	2496	7808	972	60	187	8	808	4	12	9	2	187
A2R11	7907231	81.6	100	51.5	51.1	83.3	52839	13180	6	1	4	46	10491	234	2496	7808	1039	70	218	8	862	5	11	13	2	227
A2R12	14586250	100	100	51.5	100	89.1	28949	1590	6	2	6	62	13444	234	2496	15488	1079	33	403	217	1163	5	4	33	2	208
A2R13	17394761	100	100	100	100	88.6	17582	964	6	2	6	63	13444	234	4902	15488	1084	34	312	217	1246	14	10	16	2	212
A2R14	17852761	100	100	100	100	84.1	17189	649	6	3	6	64	13444	234	4902	15488	1053	70	290	217	1132	4	11	18	2	213
A2R15	17966400	100	100	100	100	91.5	17140	218	7	3	6	69	13444	234	4902	15488	1107	93	282	217	1153	8	7	19	2	215
A2R16	18101275	100	100	100	100	94.4	17140	467	6	3	6	64	13444	234	4902	15488	1131	209	278	217	1242	8	9	18	2	229
A2R17	18176702	100	100	100	100	97.1	17140	252	6	3	6	66	13444	234	4902	15488	1149	40	294	217	1270	8	9	19	2	239
A2R18	20989042	100	100	100	100	84.1	13802	1269	7	3	6	64	13444	234	4902	15488	1049	296	231	217	1327	18	9	13	3	216
A2R19	21106317	100	100	100	100	84.5	13858	425	7	3	6	63	13444	234	4902	15488	1049	91	349	217	1201	14	9	24	4	218
A2R20	21235453	100	100	100	100	87.7	13802	94	7	3	6	65	13444	234	4902	15488	1075	279	337	217	1105	15	6	20	4	200
A2R21	21695176	100	100	100	100	96.9	13802	163	7	3	6	64	13444	234	4902	15488	1149	61	537	217	1291	14	42	19	2	227
A2R22	21959616	100	100	100	100	97.3	13802	99	6	3	6	61	13444	234	4902	15488	1149	292	540	217	1102	14	9	37	3	261
A2R23	24294716	100	100	100	100	87.4	11982	475	7	3	6	61	13444	234	4902	15488	1071	262	502	217	1102	16	49	16	4	223
A2R24	33837350	100	100	100	100	96.5	6904	0	7	1	5	51	13444	234	4902	15488	1149	316	227	217	1104	16	8	13	2	239
A2R25	38308039	100	100	100	100	96.8	5413	11	6	1	4	48	13444	234	4902	15488	1149	1081	547	217	1142	17	8	38	4	292
A2R26	39454095	100	100	100	100	89.8	3665	26	6	1	4	37	13444	234	4902	15488	1084	55	533	217	1119	15	46	28	3	195
A2R27	39976563	100	100	100	100	97.0	3665	6	6	1	3	36	13444	234	4902	15488	1149	45	544	217	1102	16	12	37	3	230

A2R28	45566724	100	100	100	100	97.3	713	0	5	1	3	26	13444	234	4902	15488	1149	62	541	217	1164	15	56	21	4	224
A2R29	48479540	100	100	100	100	90.7	0	0	5	1	3	30	13444	234	4902	15488	1093	41	448	217	1114	16	5	37	4	226
A2R30	48777316	100	100	100	100	96.5	0	0	5	1	2	23	13444	234	4902	15488	1149	123	283	217	1102	16	9	18	3	224

Villahermosa

The third case study is related to the flood occurred on the city of Villahermosa on 2007. This flood is the worst disaster of its kind in recent history in the country; therefore the number of people affected required a large-scale response from Mexican authorities. Therefore three scenarios were developed to provide a plan for disaster preparedness in the area. Initially, Table G.13 displays the characteristics of the non-dominated solutions obtained from the preparedness model for a situation of flooding of 1 meter in the city.

Table G.13. Metrics of the efficient points for the preparedness scenario of 1 meter in Villahermosa

SOL	COST	AGENCIES	FILL RATE				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES						SHELTER (%)
			FOOD	MED	NVH	NVS	SHELTERS	DCS	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	H	TRIPS	AVG OCCUPANCY
T0ND1	9124407	2	0	0	0	1.09	51	0	0	0	100	0	0	0	0	0	0	0	99.92
T0ND2	9146623	2	0	0	0	1.09	27	0	0	0	100	0	0	0	0	0	0	0	98.27
T0ND3	9191928	4	0	0	0	5.33	62	0	0	0	100	0	0	0	0	0	0	0	99.80
T0ND4	9286350	5	0	0	0	8.36	47	0	0	0	100	0	0	0	0	0	0	0	95.48
T0ND5	9522204	5	0	0	0	8.36	72	0	0	0	100	0	0	0	0	0	0	0	95.58
T0ND6	10003496	7	0	0	8.16	8.28	100	0	0	0	100	100	0	0	0	0	0	0	94.78
T0ND7	10051341	6	0	0	0	39.27	70	0	0	0	100	0	0	0	0	0	0	0	95.61
T0ND8	10304238	7	0	0	5.09	39.21	92	0	0	0	100	100	0	0	0	0	0	0	94.53
T0ND9	10524101	8	0	0	8.24	38.20	68	0	0	0	100	100	0	0	0	0	0	0	91.77
T0ND10	10752242	8	40.32	0	3.27	39.26	86	2	99.88	0	100	100	6	2	2	1	0	26	97.41
T0ND11	11002154	8	39.92	0	3.27	39.21	62	2	98.88	0	100	100	3	3	1	1	0	23	92.04
T0ND12	11137146	9	39.35	0	8.31	39.24	87	2	97.4	0	100	100	6	1	0	1	0	16	94.10
T0ND13	11308056	9	35.02	0	8.36	39.27	93	2	86.76	0	100	100	2	1	7	0	0	29	92.10
T0ND14	11472251	7	0	0	3.27	39.19	41	0	0	0	100	100	0	0	0	0	0	0	87.59

T0ND15	11580015	9	39.51	0	8.04	38.99	86	3	97.84	0	100	100	4	13	1	1	1	27	88.95
T0ND16	11684190	9	38.97	0	8.36	39.27	93	1	96.64	0	100	100	3	0	0	1	0	24	85.61
T0ND17	12065370	9	40.28	0	8.36	39.22	94	1	99.76	0	100	100	3	1	9	1	0	31	86.89
T0ND18	12386557	9	37.66	0	8.26	39.26	86	2	93.24	0	100	100	2	1	9	1	0	12	82.00
T0ND19	12502380	9	39.06	0	8.36	39.07	113	3	96.8	0	100	100	6	2	2	2	0	59	82.54
T0ND20	13072803	9	38.78	0	8.36	39.18	59	1	96	0	100	100	1	0	1	1	0	8	72.24
T0ND21	13553850	9	40	0	8.25	38.94	112	3	99.08	0	100	100	4	2	7	2	1	34	72.05
T0ND22	13618075	9	39.78	0	8.36	38.99	79	1	98.6	0	100	100	3	15	2	1	0	17	76.36
T0ND23	13653706	9	40.21	0	8.36	39.22	90	1	99.52	0	100	100	5	1	1	1	0	20	72.36
T0ND24	14082656	5	40.17	0	12.21	100	103	3	99.64	0	54.02473	100	8	2	0	3	1	62	87.59
T0ND25	14561401	8	40.16	1.81	99.86	39.18	65	4	99.4	100	100	100	4	1	1	0	0	17	97.30
T0ND26	14795498	8	40.39	4.04	99.46	39.25	57	1	100	100	100	100	1	1	1	2	0	15	92.46
T0ND27	14939255	8	40.12	4.04	99.03	39.27	72	1	99.32	100	100	100	6	2	0	1	0	16	88.83
T0ND28	15159339	8	40.10	3.17	99.79	39.26	97	4	99.28	100	100	100	5	3	2	4	0	46	90.40
T0ND29	15646509	8	39.37	3.78	99.62	39.27	57	1	97.44	100	100	100	1	1	1	0	0	6	77.79
T0ND30	16040674	8	38.39	3.17	99.67	39.26	97	4	95.08	100	100	100	5	2	2	2	0	37	84.88
T0ND31	16134796	8	40.35	3.61	99.75	39.27	72	4	99.88	100	100	100	6	1	1	1	0	17	81.18
T0ND32	16679614	8	40.22	4.04	99.41	39.24	59	1	99.56	100	100	100	1	2	0	0	0	7	78.04
T0ND33	16871011	8	40.16	3.17	99.18	39.11	97	3	99.4	100	100	100	3	1	7	3	0	22	79.89
T0ND34	17165879	8	40.18	4.04	99.34	39.27	58	2	99.52	100	100	100	1	1	1	0	0	8	64.32
T0ND35	17813173	4	38.01	3.88	99.68	100	93	2	94.08	100	64.19408	100	25	1	0	2	1	83	88.20
T0ND36	18660528	4	37.45	3.07	99.43	100	97	4	92.68	100	74.29438	100	12	10	1	2	1	77	83.29
T0ND37	20005282	4	40.40	3.23	98.47	99.93	36	4	100	100	68.18288	100	2	2	5	2	1	38	69.88
T0ND38	20024768	4	40.23	4.04	99.60	99.72	73	3	99.56	100	65.57033	100	7	1	0	2	1	54	73.75
T0ND39	21180945	4	40.36	3.75	99.62	100	65	4	99.88	100	75.32074	100	6	16	0	5	1	60	75.93
T0ND40	22103271	4	40.32	3.39	99.60	100	87	3	99.8	100	83.20504	100	7	5	0	2	1	74	68.24
T0ND41	22863486	4	40.40	3.56	98.99	99.87	48	4	100	100	86.70399	100	4	2	1	1	1	35	57.33
T0ND42	24756983	8	40.38	4.02	97.68	98.93	44	11	100	100	84.48453	99.73	4	4	7	3	4	29	53.01

T0ND43	24862889	5	40.31	1.21	98.24	97.17	71	5	99.76	50	84.71962	98.60	4	2	2	2	4	57	52.01
T0ND44	24978160	5	39.39	2.88	98.36	99.04	94	5	97.52	90	75.41021	100	5	4	9	4	1	53	51.35
T0ND45	25235766	4	39.97	3.94	99.12	100	52	2	98.92	100	94.19174	100	2	2	2	1	1	24	49.72
T0ND46	25651686	4	39.18	4.04	99.83	100	50	3	96.96	100	82.9951	100	7	3	1	2	1	47	55.24
T0ND47	26646488	4	40.40	3.40	99.55	100	48	4	100	90	88.33683	100	3	4	3	4	1	33	48.33
T0ND48	28081846	4	40.40	4.04	99.09	99.10	43	5	100	100	71.75181	98.88	4	2	3	2	1	26	42.20
T0ND49	28514322	4	40.40	3.89	99.50	100	37	3	100	100	99.41684	100	4	3	8	2	1	25	41.37
T0ND50	28862196	4	40.11	3.90	98.73	100	90	3	99.28	100	72.66153	100	10	3	2	2	1	72	47.13
T0ND51	30923079	5	40.40	3.78	98.06	99.38	41	7	100	100	86.95018	100	4	1	5	1	4	35	37.96
T0ND52	31215913	6	39.26	3.96	98.02	99.45	54	2	97.36	100	93.0459	100	1	2	1	1	1	12	32.23
T0ND53	31403730	4	38.38	4.04	99.78	99.88	37	3	95	100	85.00117	100	3	16	3	1	1	31	37.74
T0ND54	32807350	6	40.39	3.22	97.56	99.87	38	6	100	80	87.34468	100	0	1	2	4	1	21	31.95
T0ND55	33765202	4	40.40	3.93	98.58	100	51	6	100	100	97.36412	100	13	3	4	4	1	35	35.87
T0ND56	35197249	8	40.40	4.04	98.70	99.97	49	9	100	100	74.72302	100	5	2	8	9	4	44	31.96
T0ND57	35633936	7	40.23	3.73	98.67	100	70	11	99.56	100	93.1592	100	11	5	4	6	4	36	31.15
T0ND58	36131148	7	40.40	4.04	98.44	99.99	61	10	100	100	90.5347	100	9	10	7	4	1	84	32.09
T0ND59	37086128	6	40.39	4.04	98.64	98.81	51	8	100	100	87.58351	100	2	3	3	2	1	24	28.86
T0ND60	40832476	8	40.40	4.04	98.94	99.84	223	7	100	100	94.24342	100	10	11	1	6	4	58	43.11
T0ND61	41180571	4	40.02	1.48	97.23	99.35	85	2	99.04	80	90.83275	100	7	3	3	2	1	35	25.41
T0ND62	44483566	4	40.24	4.04	99.15	99.88	109	3	99.6	100	57.75601	100	8	4	2	3	1	82	27.25
T0ND63	62689053	12	40.38	3.30	97.85	99.96	124	13	100	100	95.0714	100	42	3	5	6	4	91	20.47
T0ND64	65686294	12	40.36	3.45	97.25	98.63	153	11	100	100	93.10143	100	11	3	4	9	4	136	22.44
T0ND65	88600375	12	40.40	9.63	98.52	99.44	207	15	100	100	96.54458	99.94	4	1	11	9	4	76	22.30
T0ND66	95490744	13	40.38	11.77	99.45	100	149	18	100	100	98.79445	100	10	4	10	10	4	152	22.35
T0ND67	96111124	13	40.40	10.92	98.82	99.63	155	20	100	100	90.31296	100	13	11	8	11	4	173	24.49
T0ND68	97366178	13	40.29	10.55	97.26	99.96	153	20	100	100	97.40623	100	9	9	5	11	4	113	25.74

Similarly, Table G.14 displays the features of the 66 points obtained for a flood of 2 meters in the city of Villahermosa

Table G.14. Metrics of the efficient points for the preparedness scenario of 2 meters in Villahermosa

SOL	COST	AGENCIES	FILL RATE				FACILITIES		USE RELIEF ITEMS (%)		USE HUMAN RESOURCES (%)		VEHICLES						SHELTERS (%)
			FOOD	MED	NVH	NVS	SHELTERS	DCS	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	H	TRIPS	AVG OCCUPANCY
T1ND1	18235310	2	0.00	0.00	0.00	0.54	62	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.98
T1ND2	18238772	2	0.00	0.00	0.00	0.55	61	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.90
T1ND3	18262019	3	0.00	0.00	0.00	1.44	55	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.89
T1ND4	18338088	4	0.00	0.00	0.00	2.97	83	0	N/A	N/A	100.00	0	0	0	0	0	0	0	98.90
T1ND5	18376761	5	0.00	0.00	0.00	4.17	101	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.34
T1ND6	18386579	5	0.00	0.00	0.00	4.12	92	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.40
T1ND7	18462023	5	0.00	0.00	0.00	4.16	84	0	N/A	N/A	100.00	0	0	0	0	0	0	0	97.49
T1ND8	19034439	5	0.00	0.00	0.00	17.86	143	0	N/A	N/A	100.00	0	0	0	0	0	0	0	98.07
T1ND9	19102616	6	0.00	0.00	0.00	19.62	84	0	N/A	N/A	100.00	0	0	0	0	0	0	0	99.08
T1ND10	19215365	6	0.00	0.00	0.00	19.64	96	0	N/A	N/A	100.00	0	0	0	0	0	0	0	97.44
T1ND11	19226507	6	0.00	0.00	0.00	19.62	88	0	N/A	N/A	100.00	0	0	0	0	0	0	0	96.71
T1ND12	19432933	7	0.00	0.00	1.64	19.64	80	0	N/A	N/A	100.00	100	0	0	0	0	0	0	97.36
T1ND13	19668308	7	0.00	0.00	1.64	19.58	63	0	N/A	N/A	100.00	100	0	0	0	0	0	0	91.40
T1ND14	19804908	7	0.00	0.00	1.64	19.62	77	0	N/A	N/A	100.00	100	0	0	0	0	0	0	93.93
T1ND15	19968862	8	0.00	0.00	4.18	19.64	72	0	N/A	N/A	100.00	100	0	0	0	0	0	0	96.46
T1ND16	20673752	9	19.12	0.00	4.18	19.64	79	1	94.64	N/A	100.00	100	2	1	1	1	0	12	93.83
T1ND17	21494953	3	0.00	0.00	2.75	99.67	108	0	N/A	N/A	90.55	100	0	0	0	0	1	0	99.40
T1ND18	21602518	3	0.00	0.00	3.64	99.98	128	0	N/A	N/A	91.68	100	0	0	0	0	0	0	97.98
T1ND19	22311929	6	5.13	0.00	6.01	98.93	177	5	25.44	N/A	93.43	100	14	3	2	4	1	94	94.46
T1ND20	22327787	4	0.00	0.00	5.43	99.96	158	0	N/A	N/A	96.51	100	0	0	0	0	0	0	93.45
T1ND21	22395749	5	19.77	0.00	6.18	99.87	109	2	97.84	N/A	98.89	100	23	1	0	2	1	76	98.43
T1ND22	22573822	5	19.44	0.00	6.18	99.48	100	3	96.24	N/A	94.12	100	7	10	2	2	1	58	96.06
T1ND23	22688846	4	20.04	0.00	3.64	99.72	112	3	99.2	N/A	94.58	100	8	2	2	3	1	80	95.13
T1ND24	22777355	5	18.60	0.00	6.18	99.19	101	3	92.08	N/A	99.97	100	6	3	2	3	0	56	94.51
T1ND25	24771408	5	19.93	0.00	6.18	98.51	85	3	98.68	N/A	97.07	100	5	1	2	2	1	39	86.89

T1ND26	25621728	3	18.39	0.00	2.00	97.33	97	1	91	N/A	100.00	100	1	2	1	0	0	5	74.20
T1ND27	25816644	5	3.47	1.30	66.11	99.64	128	3	17.2	100	91.96	100	13	2	3	3	1	40	99.35
T1ND28	26344157	6	17.44	1.17	68.88	99.70	95	3	86.36	80	94.66	100	5	3	1	3	1	55	96.59
T1ND29	26363563	6	20.20	1.95	69.15	99.66	62	3	100	100	98.91	100	7	3	2	2	1	30	96.82
T1ND30	26641429	6	19.96	2.02	68.91	99.72	65	2	98.8	100	100.00	100	2	3	11	0	0	11	90.47
T1ND31	27083420	6	19.36	1.69	69.15	99.68	91	4	95.88	100	100.00	100	5	4	1	3	1	59	92.52
T1ND32	27322931	6	20.09	1.72	69.12	99.18	93	4	99.44	100	99.37	100	23	2	1	4	1	49	91.22
T1ND33	28203620	6	19.22	1.98	69.17	100.00	96	2	95.2	100	99.49	100	6	2	2	2	1	44	84.83
T1ND34	28474498	6	19.93	1.44	69.16	99.93	86	4	98.68	100	98.49	100	20	3	1	3	1	42	86.01
T1ND35	29416350	6	19.84	2.02	68.54	98.96	85	2	98.24	100	95.43	100	3	2	0	1	1	14	76.14
T1ND36	31284488	9	19.58	2.02	68.92	88.95	67	1	96.92	100	83.18	100	2	0	0	1	0	15	71.16
T1ND37	31341208	5	19.76	1.21	63.94	94.96	99	4	97.92	100	91.94	100	7	4	4	4	1	74	76.40
T1ND38	32138314	5	20.20	1.60	67.06	97.65	89	5	100	100	98.74	100	7	4	1	3	1	48	75.24
T1ND39	33796314	6	16.59	1.89	66.74	96.46	79	4	82.24	100	95.89	100	25	1	0	3	1	23	64.41
T1ND40	34428979	6	19.98	1.88	66.58	96.67	86	2	99	100	94.32	100	8	3	1	2	1	21	55.78
T1ND41	34714253	7	6.92	0.41	67.82	96.24	94	1	34.24	20	95.77	100	2	1	1	1	0	3	63.14
T1ND42	34973442	6	20.01	1.06	68.69	99.52	142	4	99.08	100	93.83	100	7	1	0	3	1	60	70.41
T1ND43	36155358	6	20.05	1.73	68.03	99.47	112	3	99.24	100	92.23	100	4	2	9	2	1	40	67.00
T1ND44	36971439	6	15.51	1.56	68.22	98.89	145	3	76.8	100	91.09	100	6	3	1	2	1	63	66.00
T1ND45	37398326	6	18.74	1.03	68.75	98.85	142	3	92.8	100	90.02	100	6	2	1	3	1	60	64.84
T1ND46	38725311	9	19.86	2.02	68.57	99.48	61	4	98.28	100	93.71	100	4	2	2	1	1	37	51.49
T1ND47	40823423	8	20.14	2.00	68.21	98.84	115	3	99.76	100	95.11	100	3	3	1	1	1	21	49.71
T1ND48	41453237	6	20.12	0.98	68.04	98.10	141	5	99.64	100	100.00	100	7	3	2	5	1	76	60.83
T1ND49	42137796	8	18.75	1.03	68.16	99.45	131	8	92.88	100	96.49	100	12	11	4	4	1	65	58.20
T1ND50	42621605	6	19.96	1.14	68.09	99.58	140	3	98.84	90	99.10	100	8	8	3	3	1	87	60.68
T1ND51	43204831	6	19.86	1.37	68.32	99.31	141	3	98.36	100	96.75	100	15	4	3	3	1	86	54.31
T1ND52	45039756	6	18.78	1.00	66.37	98.39	150	4	93.08	100	90.55	100	6	5	1	3	1	54	50.95
T1ND53	45649289	6	20.16	1.80	68.60	99.08	150	3	99.88	100	95.24	100	5	16	2	2	1	59	50.31

T1ND54	46928276	7	19.57	1.38	68.32	97.93	133	3	96.96	100	93.82	100	8	2	2	3	1	38	41.07
T1ND55	48163613	6	19.37	1.57	68.60	98.91	168	4	95.96	100	92.67	100	7	3	7	3	1	82	51.33
T1ND56	50949908	11	20.20	1.93	68.56	98.43	145	9	100	100	91.41	100	9	5	4	4	4	90	42.31
T1ND57	51836045	11	20.21	1.85	68.19	97.76	157	12	100	100	95.64	100	15	11	6	7	4	143	46.78
T1ND58	71270588	4	18.22	3.70	98.11	98.40	116	5	90.16	100	95.60	100	3	5	3	3	1	24	47.76
T1ND59	72308850	4	19.89	3.36	98.84	98.19	108	4	98.44	90	97.72	100	4	2	9	1	0	31	49.04
T1ND60	73121692	5	20.21	2.94	98.53	98.97	123	5	100	95	96.92	100	4	3	9	7	2	39	46.34
T1ND61	75172659	7	16.56	3.64	98.50	98.87	116	7	82	100	100.00	100	6	7	4	4	4	42	47.30
T1ND62	76447823	6	20.21	2.67	98.75	99.64	148	6	100	100	98.15	99.96	9	7	6	6	3	91	50.95
T1ND63	85654704	5	19.89	5.50	97.57	98.57	186	3	98.44	96.66667	99.99	99.65	9	6	3	4	1	112	44.52
T1ND64	88280049	6	19.67	4.60	99.36	99.06	146	5	97.36	96.66667	100.00	100	8	4	7	5	3	101	51.39
T1ND65	98822214	13	20.20	5.03	96.89	97.63	214	12	100	100	99.99	100	8	6	4	4	4	102	43.85
T1ND66	1.01E+08	13	20.21	5.48	97.44	99.28	340	10	100	100	100.00	100	10	4	1	10	4	105	43.77

On the other hand, Table G.15 exhibits the metrics for all of the efficient solutions identified for the emulation of preparedness for the real conditions of the flood of 2007 in Villahermosa.

Table G.15. Metrics of the efficient points for the preparedness scenario of 4 meters in Villahermosa

SOL	**COST**	**AGENCIES**	**FILL RATE (%)**				**FACILITIES**		**USE RELIEF ITEMS (%)**		**USE HUMAN RESOURCES (%)**		**VEHICLES**						**SHELTERS**	**EVACUATION**
			FOOD	MED	NVH	NVS	SHELTERS	DCS	FOOD	MED	OPERATIVE	HEALTHCARE	S	M	L	B	H	TRIPS	AVG OCCUPANCY	DISTANCE P/PERSON
T2ND1	36453515	2	0	0	0	0.27	135	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.99	6.03
T2ND2	36453649	2	0	0	0	0.27	135	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.98	5.97
T2ND3	36481603	2	0	0	0	0.76	135	0	N/A	N/A	100	N/A	0	0	0	0	0	0	100	6.22
T2ND4	36499263	3	0	0	0	1.03	138	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.90	5.96
T2ND5	36499695	3	0	0	0	1.03	135	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.98	6.08
T2ND6	36521987	4	0	0	0	1.48	138	0	N/A	N/A	100	N/A	0	0	0	0	0	0	100	6.13
T2ND7	36548630	4	0	0	0	1.48	138	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.83	5.92

T2ND8	36564589	5	0	0	0	2.09	142	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.96	5.92
T2ND9	36567566	5	0	0	0	2.09	138	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.93	6.07
T2ND10	36570511	5	0	0	0	2.09	136	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.97	5.94
T2ND11	36575428	5	0	0	0	2.09	133	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.96	5.90
T2ND12	36589051	5	0	0	0	2.09	134	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.88	5.83
T2ND13	36608888	5	0	0	0	2.09	139	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.50	5.99
T2ND14	36710770	5	0	0	0	2.09	168	0	N/A	N/A	100	N/A	0	0	0	0	0	0	98.70	5.87
T2ND15	36983351	5	0	0	0	2.09	146	0	N/A	N/A	100	N/A	0	0	0	0	0	0	98.20	6.07
T2ND16	37263289	6	0	0	0	9.79	177	0	N/A	N/A	100	N/A	0	0	0	0	0	0	99.55	6.04
T2ND17	37538719	6	0	0	0	9.81	170	0	N/A	N/A	100	N/A	0	0	0	0	0	0	98.39	6.13
T2ND18	37808857	7	0	0	0.82	9.81	184	0	N/A	N/A	100	100	0	0	0	0	0	0	98.42	6.10
T2ND19	38088221	7	10.10	0	0	9.82	182	1	100	N/A	100	N/A	6	2	0	2	0	70	98.77	6.06
T2ND20	38367084	8	10	0	0.80	9.82	156	1	99.04	N/A	100	100	1	3	10	1	0	26	98.62	5.80
T2ND21	38640878	9	10.10	0	2.09	9.82	157	1	100	N/A	100	100	4	4	8	2	0	73	98.51	5.88
T2ND22	39194770	9	10.09	0	2.09	9.74	190	2	100	N/A	100	100	6	5	5	3	1	93	96.40	6.04
T2ND23	39470641	9	10.06	0	2.09	9.80	196	2	99.64	N/A	100	100	5	3	5	2	0	58	96.09	6.14
T2ND24	39638281	2	0	0	1.00	57.24	136	0	N/A	N/A	100	100	0	0	0	0	0	0	99.53	6.02
T2ND25	39647916	3	0	0	1.00	57.52	135	0	N/A	N/A	100	100	0	0	0	0	0	0	99.89	6.05
T2ND26	39713482	4	0	0	1.00	58.28	141	0	N/A	N/A	100	100	0	0	0	0	0	0	99.67	6.07
T2ND27	39737452	6	0	0	1.00	59.33	155	0	N/A	N/A	100	100	0	0	0	0	0	0	99.89	6.01
T2ND28	39742639	6	0	0	1.00	59.32	151	0	N/A	N/A	100	100	0	0	0	0	0	0	99.86	6.35
T2ND29	39746239	6	0	0	1.00	59.33	145	0	N/A	N/A	100	100	0	0	0	0	0	0	99.90	5.95
T2ND30	39752399	6	0	0	1.00	59.35	132	0	N/A	N/A	100	100	0	0	0	0	0	0	99.93	6.09
T2ND31	39785881	6	0	0	1.00	59.34	136	0	N/A	N/A	100	100	0	0	0	0	0	0	99.58	6.18
T2ND32	39815941	6	0	0	1.00	59.34	140	0	N/A	N/A	100	100	0	0	0	0	0	0	99.65	6.15
T2ND33	40011502	6	0	0	1.00	59.35	134	0	N/A	N/A	100	100	0	0	0	0	0	0	98.31	5.93
T2ND34	40019873	6	0	0	1.00	59.34	149	0	N/A	N/A	100	100	0	0	0	0	0	0	98.47	6.07
T2ND35	40294627	4	0	0	0.96	65.25	154	0	N/A	N/A	100	100	0	0	0	0	0	0	99.89	6.21

T2ND36	40439726	7	0	0	1.00	67.07	137	0	N/A	N/A	100	100	0	0	0	0	0	0	99.86	5.88
T2ND37	40569755	8	0	0	2.24	67.05	144	0	N/A	N/A	100	100	0	0	0	0	0	0	99.40	6.21
T2ND38	40605443	7	0	0	1.00	67.07	138	0	N/A	N/A	100	100	0	0	0	0	0	0	97.89	5.96
T2ND39	40723801	7	0	0	1.00	67.07	141	0	N/A	N/A	100	100	0	0	0	0	0	0	98.06	6.05
T2ND40	40754915	7	0	0	1.00	67.06	134	0	N/A	N/A	100	100	0	0	0	0	0	0	98.11	5.93
T2ND41	40867496	8	0	0	1.82	67.07	138	0	N/A	N/A	100	100	0	0	0	0	0	0	97.86	6.03
T2ND42	40939430	9	0	0	3.09	67.02	151	0	N/A	N/A	100	100	0	0	0	0	0	0	98.05	6.09
T2ND43	41005887	8	0	0	1.82	67.08	142	0	N/A	N/A	100	100	0	0	0	0	0	0	97.29	5.90
T2ND44	41075621	8	0	0	1.82	67.06	146	0	N/A	N/A	100	100	0	0	0	0	0	0	97.40	6.19
T2ND45	41125798	8	9.95	0	1.00	67.06	143	2	98.48	N/A	100	100	2	2	4	2	0	30	99.56	6.09
T2ND46	41195439	9	0	0	3.09	67.08	145	0	N/A	N/A	100	100	0	0	0	0	0	0	97.40	6.28
T2ND47	41401851	10	8.12	0	3.09	66.85	167	3	80.56	N/A	100	100	2	2	3	3	2	49	97.95	5.88
T2ND48	41456103	9	9.93	0	1.82	67.08	140	2	98.28	N/A	100	100	2	2	5	1	0	16	98.25	6.19
T2ND49	41677659	10	9.27	0	3.07	66.99	177	3	91.96	N/A	100	100	4	1	1	2	0	39	97.32	5.92
T2ND50	41724606	10	9.46	0	3.09	67.06	159	3	93.64	N/A	100	100	3	3	1	3	0	37	97.41	5.99
T2ND51	41856092	10	9.87	0	3.09	67.06	149	1	97.72	N/A	100	100	1	1	11	0	0	14	93.99	6.16
T2ND52	41949477	10	10.10	0	3.03	66.96	171	3	100	N/A	100	100	4	2	4	2	1	58	96.22	6.01
T2ND53	42229520	10	9.90	0	3.00	67.04	189	1	98.04	N/A	100	100	4	1	1	1	0	44	93.97	6.22
T2ND54	42505371	10	9.90	0	3.05	66.95	174	1	98.04	N/A	100	100	21	5	0	1	1	47	94.06	5.90
T2ND55	42780510	10	7.19	0	3.06	67.01	191	2	71.4	N/A	100	100	21	3	0	1	0	23	92.41	5.90
T2ND56	43057149	10	10.09	0	3.08	67.01	176	2	99.92	N/A	100	100	4	1	1	2	1	48	91.31	6.05
T2ND57	43326364	10	10.10	0	3.09	66.93	182	4	100	N/A	100	100	4	7	1	1	2	30	92.16	5.78
T2ND58	43607544	10	10.10	0	3.06	66.88	187	2	100	N/A	100	100	2	4	5	1	2	50	89.49	6.00
T2ND59	43878542	10	10.06	0	3.00	66.95	220	3	100	N/A	100	100	8	1	5	4	0	98	86.71	5.90
T2ND60	44160609	8	0	0.24	33.09	59.08	153	1	N/A	30	100	100	1	0	0	0	0	3	97.94	6.03
T2ND61	44434853	8	0	0.55	32.53	66.83	144	1	N/A	70	100	100	1	0	0	0	0	7	99.48	5.84
T2ND62	44712442	9	0	0	33.36	67.03	139	0	N/A	0	100	100	0	0	0	0	0	0	97.75	6.17
T2ND63	44988273	9	4.62	0.96	32.28	66.90	160	3	45.84	100	100	100	5	3	3	1	2	58	98.67	6.09

T2ND64	45262184	9	10.09	0.67	32.32	66.79	170	3	100	100	100	100	5	3	2	2	2	51	98.33	5.98
T2ND65	45368267	11	7.99	0.94	34.63	67.03	141	3	79.16	100	100	100	16	2	1	3	0	29	98.11	6.11
T2ND66	45540170	11	10.04	0.85	34.62	67.00	143	2	99.44	90	100	100	2	2	6	2	1	25	98.09	6.09
T2ND67	45620222	11	7.80	0.98	34.58	67.05	157	2	77.24	100	100	100	3	3	2	1	0	26	96.17	5.90
T2ND68	45626285	11	8.21	0.91	34.60	67.04	150	2	81.28	100	100	100	1	17	1	3	0	29	97.10	5.85
T2ND69	45650424	11	8.39	1.01	34.58	67.04	139	1	83.08	100	100	100	1	1	11	0	0	12	96.80	5.93
T2ND70	45803022	11	10.10	0.95	34.64	67.05	151	2	100	100	100	100	2	6	1	1	0	35	94.55	6.19
T2ND71	45919589	11	10.09	0.96	34.63	67.04	152	3	100	100	100	100	3	5	1	2	0	22	94.36	5.91
T2ND72	46042272	11	8.86	0.61	34.60	67.06	147	1	87.72	60	100	100	1	20	1	0	0	14	94.43	5.90
T2ND73	46081943	11	9.28	0.92	34.64	66.98	153	2	91.92	100	100	100	3	3	3	2	1	42	95.44	6.07
T2ND74	46124405	11	8.92	0.97	34.57	67.06	159	3	88.28	100	100	100	2	2	1	1	0	21	93.70	6.10
T2ND75	46202706	11	8.84	0.96	34.64	67.00	156	2	87.6	100	100	100	2	4	8	2	0	25	92.16	5.83
T2ND76	46247181	11	10.02	0.91	34.63	67.04	150	1	99.16	90	100	100	1	2	2	0	0	12	92.32	6.11
T2ND77	46334197	11	9.58	1.01	34.57	67.02	151	2	94.92	100	100	100	6	2	1	6	0	12	93.12	5.94
T2ND78	46367524	11	9.42	0.53	34.60	66.98	168	3	93.32	100	100	100	3	1	2	0	1	31	93.42	6.05
T2ND79	46397816	11	9.34	0.99	34.63	66.98	162	3	92.48	100	100	100	9	2	2	2	1	36	94.45	6.00
T2ND80	46506509	11	9.24	0.92	34.63	67.04	156	2	91.48	100	100	100	3	17	1	0	0	21	92.66	6.05
T2ND81	46698386	11	9.28	0.99	34.63	66.95	159	3	91.92	100	100	100	3	8	4	0	0	26	91.79	6.13
T2ND82	46886197	11	9.79	0.99	34.62	67.03	165	2	96.88	100	100	100	2	2	2	2	0	22	92.09	6.16
T2ND83	47017346	11	10.08	0.79	34.60	66.96	178	4	99.88	100	100	100	5	2	1	3	1	50	91.13	6.04
T2ND84	47101879	11	9.98	0.75	34.56	66.88	177	4	98.88	100	100	100	4	4	3	2	2	53	91.97	5.94
T2ND85	47174924	11	10.09	0.73	34.57	66.71	177	3	100	100	100	100	4	2	3	2	2	51	91.73	5.99
T2ND86	47368465	11	9.95	0.78	34.63	66.99	184	3	98.6	100	100	100	5	2	3	2	1	49	90.43	5.98
T2ND87	47950759	11	10.05	0.43	34.48	66.62	232	4	100	100	100	100	7	2	1	5	3	106	89.42	6.10
T2ND88	48298933	11	10.03	0.55	34.46	66.90	222	3	99.68	100	100	100	8	4	2	3	0	93	85.95	6.05
T2ND89	48777407	11	10.07	0.44	34.50	66.53	243	4	100	100	100	100	5	6	1	4	3	104	83.14	6.15
T2ND90	48868342	11	10.08	0.62	34.34	66.68	251	3	100	100	100	100	1	1	0	5	2	61	79.79	6.05
T2ND91	52161355	4	5.46	0.63	31.43	97.77	176	4	54.12	100	100	100	6	5	6	4	0	74	99.46	6.09

T2ND92	52712926	8	10.08	0.74	32.57	96.64	193	6	100	100	100	100	36	106	10	5	0	110	98.36	6.17
T2ND93	53219789	6	10.09	0.69	33.40	95.49	159	5	99.96	90	100	100	4	4	11	2	0	25	95.41	5.97
T2ND94	53260057	6	10.10	0.81	18.61	97.42	158	4	100	100	100	100	6	8	7	4	0	97	95.39	6.05
T2ND95	53530634	6	8.39	0.71	33.31	99.06	188	6	83.28	100	100	100	10	13	10	5	0	118	94.33	5.93
T2ND96	53604825	6	9.25	0.80	33.36	98.30	173	4	91.6	100	100	100	36	5	5	2	0	54	93.29	5.97
T2ND97	53652917	6	6.01	0.72	33.53	98.94	177	5	59.6	100	100	100	34	9	5	4	0	94	93.63	5.94
T2ND98	53816778	6	10.10	0.59	33.56	98.68	172	4	100	100	100	100	7	7	6	4	0	86	91.99	5.89
T2ND99	53905921	6	9.63	0.93	33.57	98.34	164	7	95.4	100	100	100	6	8	8	6	0	91	94.26	6.11
T2ND100	54070263	7	9.71	0.49	33.36	98.34	188	7	96.2	100	100	100	8	8	10	6	0	101	93.43	5.99
T2ND101	54185763	6	10.09	0.80	33.49	99.06	185	7	99.96	100	100	100	10	6	6	6	0	101	94.20	5.91
T2ND102	54814588	7	8.76	0.75	33.41	98.18	192	7	86.68	100	100	100	6	6	9	5	0	80	91.30	6.01
T2ND103	54920252	7	10.05	0.43	33.12	98.96	218	7	99.68	100	100	100	14	99	7	6	0	139	86.90	5.95
T2ND104	55466149	10	10.09	0.56	33.22	97.52	208	7	100	100	100	100	9	9	10	6	0	135	90.36	5.97
T2ND105	56008363	10	10.08	0.50	32.99	97.12	232	8	100	100	100	100	12	15	9	6	0	184	85.76	5.98
T2ND106	56664108	11	10.07	0.45	33.38	97.62	234	9	100	100	100	100	10	68	4	8	3	199	83.96	6.22
T2ND107	59011164	11	10.08	0.58	34.37	98.50	226	9	100	100	100	100	13	15	9	6	1	218	86.36	6.02
T2ND108	59673485	12	10.09	0.67	34.27	97.93	219	12	100	100	98.04	100	10	9	6	11	4	191	87.51	5.98
T2ND109	59829805	12	10.09	0.66	34.00	99.53	230	11	100	100	99.37	100	25	32	14	11	4	322	84.09	6.14
T2ND110	59859462	12	10.08	0.69	34.31	98.61	232	9	100	100	100	100	8	9	7	11	4	188	84.18	5.73
T2ND111	59896030	12	10.07	0.54	34.23	98.48	234	10	100	100	100	100	8	9	7	9	4	192	83.80	5.94
T2ND112	59971533	12	10.06	0.46	34.12	98.82	239	10	100	100	100	100	16	23	14	11	4	313	82.27	6.04
T2ND113	60011858	12	10.07	0.64	34.17	98.68	240	12	100	100	100	100	14	16	7	11	4	281	82.53	5.88
T2ND114	71472665	7	0	1.90	99.95	59.18	158	1	N/A	100	100	99.60	1	0	0	0	1	11	97.12	5.99
T2ND115	71748626	5	0	1.87	99.97	65.16	137	1	N/A	95	100	99.60	1	0	0	0	0	3	99.89	5.95
T2ND116	72024341	8	0	1.94	99.95	66.99	150	1	N/A	100	100	99.60	0	0	0	1	1	9	99.13	5.90
T2ND117	72301166	9	5.11	2.02	99.98	67.05	137	1	50.64	100	99.97	99.93	1	0	1	1	0	14	99.67	5.95
T2ND118	72563015	9	10.10	1.89	100	67.05	142	1	100	100	100	99.86	9	2	6	6	1	19	99.56	6.03
T2ND119	72852965	9	10	2.00	99.99	67.07	144	1	99.08	100	100	99.86	2	17	2	1	1	41	97.22	6.08

T2ND120	73122216	9	10.10	1.77	99.95	67.07	161	4	100	100	100	99.86	3	3	2	4	1	52	96.85	6.04
T2ND121	73404630	9	10.06	1.60	99.99	67.08	164	3	99.64	100	100	99.86	9	2	2	3	1	67	95.50	5.99
T2ND122	73678234	9	9.78	1.93	99.91	67.08	162	3	96.92	100	99.90	99.60	2	3	2	1	1	31	94.48	5.98
T2ND123	73949390	9	10.10	1.97	99.98	67.07	169	1	100	100	100	99.86	4	2	0	1	1	39	93.69	5.95
T2ND124	74228516	9	10.09	1.33	99.98	67.07	202	4	100	100	100	99.82	6	3	2	3	1	83	92.57	5.95
T2ND125	74505530	9	10.10	1.75	99.93	67.00	178	3	100	100	99.97	99.82	5	3	2	2	1	65	92.02	6.01
T2ND126	75046489	9	10.08	0.85	99.85	67.06	224	4	100	100	100	99.75	8	2	1	5	1	93	91.60	6.01
T2ND127	75553387	9	10.09	1.18	99.93	66.87	214	4	100	100	100	99.68	4	4	1	4	4	85	89.88	6.06
T2ND128	75712452	11	10.10	1.16	99.91	66.89	218	4	100	100	100	99.61	3	1	0	5	1	64	89.67	6.03
T2ND129	76005970	11	10.10	1.01	99.88	66.92	223	4	100	100	100	99.64	3	2	0	4	3	74	89.38	6.16
T2ND130	76126425	11	10.10	1.45	99.94	66.97	230	3	100	100	100	99.75	2	1	1	3	1	52	85.88	5.99
T2ND131	79192718	3	0	1.86	99.21	94.20	148	2	N/A	100	100	100	2	1	0	0	0	18	98.40	6.03
T2ND132	79447456	4	1.16	0.51	99.56	98.32	139	7	11.48	25	100	100	5	3	1	5	0	54	98.76	5.99
T2ND133	79474238	4	2.97	1.60	99.98	99.00	158	6	29.44	95	100	100	11	6	2	5	0	112	99.32	6.19
T2ND134	79615082	4	2.97	2.02	99.97	99.76	136	6	29.36	100	100	100	9	3	1	6	0	104	98.76	6.27
T2ND135	79743811	4	6.05	2.02	100	99.97	135	4	59.88	100	100	100	11	4	1	5	0	115	98.65	5.97
T2ND136	80307033	4	5.98	2.02	99.90	99.42	156	4	59.16	100	100	100	12	5	3	5	0	125	96.22	6.01
T2ND137	80320135	4	8.23	1.87	99.91	99.63	167	6	81.48	100	100	100	18	4	7	6	0	139	96.25	5.79
T2ND138	80643186	4	10.06	2.02	99.94	99.67	152	8	99.6	100	100	100	12	4	3	6	0	117	96.00	5.88
T2ND139	80678964	4	9.41	1.97	99.93	99.59	158	6	93.16	100	100	100	12	10	8	6	0	139	94.78	5.83
T2ND140	80754155	4	10.08	2.02	99.81	99.76	151	12	99.76	100	100	100	13	102	6	6	0	120	94.86	6.04
T2ND141	80943464	4	10.04	2.02	99.95	99.61	155	10	99.44	100	100	100	13	10	2	6	0	118	94.31	5.92
T2ND142	81046066	4	10.10	1.97	99.92	99.66	159	5	100	100	100	100	10	5	4	6	0	114	93.09	5.65
T2ND143	81600270	4	10.10	2.02	99.91	99.46	184	8	100	100	100	100	21	5	3	6	0	129	92.87	5.88
T2ND144	81645648	4	10.02	2.02	99.98	99.35	167	9	99.24	100	100	100	20	9	8	6	0	115	90.92	5.98
T2ND145	82233104	4	10.07	1.89	99.48	98.97	186	8	99.72	100	100	100	36	104	5	6	0	151	89.39	5.90
T2ND146	83067259	5	10.10	1.70	99.53	99.60	191	3	99.96	100	100	100	11	2	3	6	2	136	92.48	5.83
T2ND147	83669415	11	10.10	2.00	99.84	99.46	202	8	100	100	100	100	8	9	8	9	3	184	92.02	5.93

T2ND148	83687147	10	10.10	1.84	99.71	99.52	201	13	100	100	100	100	36	103	5	10	3	142	91.37	6.17
T2ND149	87674404	12	10.10	2.87	99.73	99.28	202	14	100	100	100	100	43	107	11	11	3	231	91.28	6.07

Having the results from the preparedness model, the response model was applied to the three situations proposed to get the Pareto frontier for each one of them. Table G.16 shows the results for the first scenario.

Table G.16. Metrics of the efficient points of the response model applied to a flood of 1 meter in Villahermosa

SOL	COST	FILL RATE (%)					UNFULFILLMENT		AGENCIES (PER PERIOD)				RELIEF USED					MAXIMUM PERSONNEL USED P/PERIOD				MAXIMUM NUMBER OF VEHICLES USED P/PERIOD					
		FOOD	MEDI	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PS	PH	S	M	L	B	H	TRIPS
T0ND1	50370.89	0.01	3.80	0	0	70.32	105395	108506	4	2	3	42	0	0	0	0	0	51	0	9	6	0	0	0	0	0	0
T0ND2	56305.97	0.01	3.80	0	0	70.32	105401	108375	3	0	2	26	0	0	0	0	0	51	0	17	6	0	0	0	0	0	0
T0ND3	56305.97	0.01	3.80	0	0	70.32	105395	108376	1	0	1	10	0	0	0	0	0	51	0	17	6	0	0	0	0	0	0
T0ND4	56305.97	0.01	3.80	0	0	70.32	105401	108361	2	0	2	18	0	0	0	0	0	51	0	17	6	0	0	0	0	0	0
T0ND5	56305.97	0.01	3.80	0	0	70.32	105395	108356	3	0	2	22	0	0	0	0	0	51	0	17	6	0	0	0	0	0	0
T0ND6	226199	0.01	3.80	0	0	70.49	105395	105376	2	0	2	22	0	0	0	0	2	57	11	27	6	0	0	1	0	0	2
T0ND7	348850	0.01	3.80	0	0	89.96	105395	108461	5	1	3	37	0	0	0	0	809	51	41	16	6	7	1	0	1	0	74
T0ND8	426128.7	0.01	3.80	0	0	92.30	105395	108476	3	0	2	27	0	0	0	0	1015	51	50	19	6	10	0	0	1	0	95
T0ND9	507495.8	0.01	3.80	0	0	95.76	105395	108656	1	1	1	16	0	0	0	0	1056	68	82	9	6	10	2	1	3	0	96
T0ND10	576509.9	0.01	3.80	0	0	90.58	105395	106046	2	0	2	17	0	0	0	0	993	51	49	27	6	5	4	0	2	0	99
T0ND11	666385	0.01	3.80	0	0	89.81	105395	103707	2	1	2	17	1	0	0	0	966	51	36	72	6	6	1	0	2	0	93
T0ND12	846454.2	0.01	3.80	0	0	85.53	105405	99643	5	2	3	47	0	0	0	0	810	51	25	77	6	5	0	0	1	0	90
T0ND13	1275117	0.01	3.80	0	0	87.75	105395	92708	3	0	2	29	0	0	0	0	818	51	30	147	6	6	1	0	3	0	106
T0ND14	1331308	0.01	3.80	0	0	89.23	105395	92466	4	2	3	48	0	0	0	0	952	51	31	147	6	5	1	0	2	0	99
T0ND15	1898336	0.01	24.27	0	0.01	95.41	105395	90980	1	0	1	1	0	126	0	2	1043	53	103	147	6	6	7	2	3	0	130
T0ND16	2307884	0.01	82.26	0	0	95.72	105407	90795	6	1	3	48	0	302	0	0	1046	51	101	147	6	4	12	0	3	0	107
T0ND17	2316089	0.01	67.32	0	0	95.59	105395	91255	5	0	3	34	0	316	0	0	1047	55	95	147	6	9	5	1	3	0	122

T0ND18	2515480	0.01	85.75	0	0	95.63	105395	91125	4	1	3	45	0	388	0	0	1044	51	116	147	6	1	17	0	3	0	98
T0ND19	2751568	0.01	81.09	0	0	95.68	105395	88920	3	0	2	25	0	378	0	0	1055	51	99	198	6	7	5	8	4	0	110
T0ND20	3130385	0.02	81.35	0	0	100	105395	83621	2	2	2	32	2	353	0	1	1216	51	111	636	6	5	9	1	3	3	109
T0ND21	3473947	0.01	100	0	0	98.51	105395	82376	7	2	5	66	0	456	0	0	1157	51	119	628	6	3	12	1	3	3	113
T0ND22	3746370	0.01	72.75	0	0	99.53	105395	75296	2	0	1	2	0	325	0	1	1195	52	106	657	6	9	4	1	6	2	108
T0ND23	4362383	0.03	64.46	0	0	99.88	105395	68321	3	2	3	33	4	323	0	1	1214	51	107	657	6	5	9	1	3	2	109
T0ND24	4809187	0.01	99.44	0	0	99.46	105395	67338	6	1	3	48	0	445	0	0	1180	51	141	657	6	3	12	3	3	3	118
T0ND25	4978355	0.03	58.60	0	0	100	105395	59603	1	0	1	1	4	277	0	1	1216	54	108	657	6	7	5	2	3	3	109
T0ND26	5594397	1.15	100	0	0.01	100	105395	58353	3	2	3	33	314	456	0	2	1216	54	108	657	6	8	6	1	3	3	109
T0ND27	5948651	0.01	87.30	0	0	98.83	105395	51370	6	0	3	40	0	374	0	0	1169	52	110	657	6	5	7	2	3	3	127
T0ND28	5989375	0.01	92.03	0	0	97.14	105395	51082	5	2	4	52	0	389	0	0	1141	51	117	657	6	5	10	1	3	3	119
T0ND29	6021283	0.01	91.46	0	0	97.82	105395	50815	5	2	4	60	0	397	0	0	1151	51	111	657	6	4	8	2	3	3	108
T0ND30	6138049	0.01	100	0	0	100	105395	51373	4	1	3	44	0	456	0	0	1216	51	111	657	6	6	10	0	3	3	115
T0ND31	6210253	0.38	100	0	0	100	105395	50744	2	1	2	17	102	456	0	0	1216	52	110	657	6	5	7	2	3	3	110
T0ND32	6826388	1.08	100	0	0.01	100	100535	50286	2	1	2	17	298	456	0	2	1216	51	111	657	15	8	6	1	4	3	109
T0ND33	7442346	13.52	100	0	0	100	100535	50286	3	2	3	33	3797	456	0	1	1216	54	108	657	15	8	6	1	3	3	110
T0ND34	8058361	25.80	100	0	0	100	100535	50286	2	0	1	14	7296	456	0	0	1216	51	111	657	15	7	5	2	4	3	109
T0ND35	8674373	39.97	95.04	0	0.01	98.96	100535	51099	4	2	3	34	11228	436	0	2	1177	51	143	657	15	4	6	6	3	3	109
T0ND36	9290348	50.53	99.27	0	0	99.83	100535	50534	2	1	2	17	14249	454	0	1	1214	51	129	657	15	7	3	5	3	3	110
T0ND37	9906378	63.27	100	0	0	100	100535	50859	4	1	2	19	17871	456	0	0	1216	51	140	657	15	4	11	3	3	3	109
T0ND38	10522356	75.69	100	0	0	100	100535	50769	3	2	3	33	21368	456	0	0	1216	51	134	657	15	4	10	3	3	3	109
T0ND39	11138398	87.59	100	0	0	100	100535	50468	0	0	0	0	24732	456	0	1	1216	51	128	657	15	5	10	2	3	3	116
T0ND40	11754381	99.77	100	0	0	100	100535	50239	4	2	3	34	28197	456	0	1	1216	51	116	657	15	5	8	2	3	3	117
T0ND41	12370399	99.60	100	0	0	100	95495	50329	3	2	3	45	28142	456	0	1	1216	51	127	657	29	5	8	3	3	3	118
T0ND42	12667425	99.88	100	0	0	99.92	92975	50422	7	1	5	67	28227	456	0	0	1215	51	120	657	29	6	6	3	3	3	126
T0ND43	12679569	99.96	99.96	0	0	99.99	92975	50400	7	2	5	67	28247	455	0	0	1215	51	128	657	29	7	6	3	4	3	128
T0ND44	12725235	100	99.64	0	0	100	93013	49927	6	3	4	64	28260	455	0	0	1216	51	121	657	29	6	8	2	3	3	123
T0ND45	12986389	95.61	99.63	0	0	99.91	92975	47253	3	0	2	18	27016	455	0	1	1215	51	145	657	29	4	10	4	3	3	119

T0ND46	13194872	95.72	93.61	0	0	98.52	92975	45954	7	1	4	56	27051	435	0	0	1195	51	148	707	29	7	10	7	4	3	191
T0ND47	13602364	99.94	100	0.02	16.69	100	92975	46679	3	2	3	41	28243	456	1	4674	1216	53	127	657	29	5	8	3	3	3	122
T0ND48	14834378	98.97	99.18	0	0	99.91	97025	35070	4	2	3	46	27972	453	0	1	1215	135	127	1684	29	5	8	9	3	3	125
T0ND49	16682395	100	100	0	35.84	100	90843	36881	4	0	3	37	28260	456	0	10124	1216	53	115	1398	40	6	7	9	3	3	133
T0ND50	17298368	100	100	0	0.03	100	70663	45605	5	2	4	56	28260	456	0	8	1216	51	116	663	361	5	8	2	3	3	117
T0ND51	18530396	100	100	0	0.28	100	73517	35166	6	2	4	62	28259	456	0	77	1216	51	114	1684	347	7	6	2	3	3	122
T0ND52	20374094	99.97	99.88	0	9.65	99.97	69997	29128	6	2	4	61	28252	455	0	2736	1215	70	123	1684	354	4	10	8	3	3	127
T0ND53	20994392	99.82	100	0	0.55	100	49681	45001	3	0	2	30	28204	456	0	153	1216	150	110	708	350	8	4	2	4	3	118
T0ND54	22226344	99.83	98.90	0	61.43	100	69013	29736	7	2	5	70	28212	453	0	17320	1216	532	183	1601	353	3	11	7	6	4	145
T0ND55	22842357	100	100	0	0.32	100	69007	16984	5	2	4	49	28260	456	0	93	1216	51	182	2034	362	8	8	6	10	4	120
T0ND56	23257795	100	100	0	0	100	49649	31286	8	2	6	82	28260	456	0	0	1216	51	134	1684	364	8	10	3	10	3	120
T0ND57	25306370	98.23	96.21	0	0	99.12	50148	18283	6	2	4	63	27763	444	0	0	1204	52	153	1684	364	6	11	4	10	1	117
T0ND58	25649785	98.90	95.84	0	0	99.04	49636	17185	9	3	6	81	27952	443	0	0	1203	56	199	1684	358	10	8	8	10	3	157
T0ND59	26318291	99.55	100	0	0	100	49636	17195	8	2	5	76	28135	456	0	0	1216	53	219	2044	358	12	8	7	10	4	144
T0ND60	26538391	97.74	92.40	0	22.82	98.19	48970	15400	6	2	5	65	27622	430	0	6388	1177	136	159	1684	358	7	7	6	10	3	122
T0ND61	27154360	99.83	100	0	0.09	100	32888	30913	5	0	3	38	28213	456	0	28	1216	103	147	1684	354	6	5	6	3	3	135
T0ND62	28386352	99.83	99.27	0	41.13	99.75	31644	29964	7	2	5	70	28212	454	0	11575	1213	117	182	1684	361	4	9	13	10	3	124
T0ND63	30109348	100	100	0	0	100	32297	16733	7	2	5	73	28260	456	0	0	1216	51	221	2044	361	13	8	7	10	4	122
T0ND64	30234301	98.30	95.11	0.08	71.93	98.87	47664	5013	6	2	4	50	27786	441	6	20282	1201	78	194	1684	358	4	8	10	10	1	150
T0ND65	30421537	100	100	0	0	100	31631	16021	8	2	5	74	28260	456	0	0	1216	485	221	1684	364	8	8	9	10	4	179
T0ND66	30848019	99.97	100	0	29.18	100	31631	18026	7	2	4	64	28250	456	0	8337	1216	119	213	2047	357	9	5	10	4	4	147
T0ND67	32831419	100	100	0	98.82	100	31631	15258	8	2	5	76	28260	456	0	27933	1216	483	220	1684	364	8	6	10	10	4	219
T0ND68	34771905	100	100	0	78.14	100	31681	5231	6	2	5	65	28260	456	0	22114	1216	71	217	2044	364	8	6	10	11	4	268
T0ND69	34890868	100	100	0	78.47	100	31631	5137	8	2	5	72	28260	456	0	22114	1216	158	203	2047	364	8	6	9	10	4	200
T0ND70	37010396	100	100	0	25.00	100	20277	6074	7	2	5	66	28260	456	0	7017	1216	63	217	2044	364	8	6	10	15	4	136
T0ND71	37626354	100	100	0	49.27	100	19961	5975	5	0	3	44	28260	456	0	13904	1216	65	219	2044	364	8	4	11	15	4	135
T0ND72	38858359	100	100	2.46	78.08	100	19557	4351	7	2	5	71	28260	456	161	22114	1216	484	219	1684	364	8	4	11	10	4	168
T0ND73	39996850	100	100	0	99.89	100	19961	4418	7	2	5	65	28260	456	0	28229	1216	71	253	2142	364	8	6	13	11	4	324

T0ND74	40090293	98.51	94.29	50.90	97.62	98.59	18415	4001	6	2	4	57	27844	439	3313	27591	1198	135	216	1684	364	10	9	13	10	2	219
T0ND75	41322377	99.83	99.63	64.93	68.12	99.94	16729	4390	7	2	5	65	28212	455	4211	19181	1201	495	220	1688	364	18	2	11	10	4	306
T0ND76	43170393	98.74	96.21	61.48	98.74	99.12	10991	4246	7	2	5	70	27907	444	4004	27910	1204	145	200	1684	363	9	3	13	15	3	141
T0ND77	43786308	100	100	46.50	100	100	10991	4208	5	0	3	46	28260	456	3022	28263	1216	120	220	2044	364	9	1	12	11	4	150
T0ND78	45634287	100	99.63	83.71	99.63	99.91	9343	3704	7	2	5	75	28260	455	5436	28159	1215	139	182	2107	364	7	4	13	10	4	198
T0ND79	47482395	100	100	96.67	100	100	9271	776	6	2	4	56	28260	456	6292	28263	1216	108	256	2048	359	8	7	13	11	4	158
T0ND80	48714371	100	100	95.76	100	100	8621	306	7	2	5	66	28260	456	6233	28263	1216	126	264	2051	364	15	3	13	15	4	178
T0ND81	49946376	99.04	96.21	92.61	99.04	99.12	6822	804	7	2	5	71	27992	444	6025	27995	1204	106	183	1684	364	6	7	9	11	3	167
T0ND82	51794392	100	100	80.30	100	100	5657	565	6	0	4	53	28260	456	5223	28263	1216	70	221	2044	364	14	3	13	11	4	217
T0ND83	53000497	100	100	100	100	100	5479	549	8	2	6	81	28260	456	6508	28263	1216	486	263	1895	364	16	6	13	10	4	264
T0ND84	53670564	100	100	100	100	100	5479	270	7	2	4	64	28260	456	6508	28263	1216	129	183	2084	361	9	0	13	12	4	209
T0ND85	55490377	100	100	97.06	100	100	4301	636	8	2	5	74	28260	456	6311	28263	1216	147	219	2044	364	10	1	12	16	4	161
T0ND86	56715603	100	100	99.64	100	100	4106	270	7	2	5	71	28260	456	6484	28263	1216	223	232	2083	360	9	3	12	15	4	249
T0ND87	58521596	100	100	100	100	100	4106	13	6	0	4	53	28260	456	6508	28263	1216	484	224	1684	364	9	9	13	10	4	191
T0ND88	59045682	100	100	100	100	100	4106	0	8	2	5	80	28260	456	6508	28263	1216	185	218	2044	363	9	3	11	15	4	183
T0ND89	63948633	100	100	80.27	98.99	100	2610	270	7	2	4	64	28260	456	5226	27979	1216	239	198	2069	364	7	1	14	15	4	210
T0ND90	64685595	100	100	83.21	99.92	100	2610	270	8	2	5	74	28260	456	5416	28239	1216	543	222	2083	368	19	2	11	15	4	235
T0ND91	67194395	100	100	98.70	100	100	2128	308	7	2	5	71	28260	456	6419	28263	1216	139	221	2044	362	8	3	12	16	4	166
T0ND92	91848000	100	100	100	100	100	0	0	9	3	6	90	28260	456	6508	28263	1216	866	1831	10197	3156	182	134	19	21	6	16926

Similarly, the response model was employed to obtain a policy for a flood of two meters in Villahermosa, and the results are displayed on Table G.17.

Table G.17. Metrics of the efficient points of the response model applied to a flood of 2 meters in Villahermosa

SOL	COST	FILL RATE (%)					UNFULFILLMENT		AGENCIES (PER PERIOD)				RELIEF USED					MAXIMUM PERSONNEL USED P/PERIOD				MAXIMUM NUMBER OF VEHICLES USED P/PPERIOD					
		FOOD	MEDI	CKIT	PKIT	HKIT	NVH	NVS	MIN	MAX	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	B	H	TRIPS
T1ND1	636599.1	0.03	4.37	0	0	0	214380	221036	0	2	2	27	0	0	0	0	0	100	0	6	8	0	0	0	0	0	0
T1ND2	636599.1	0.03	4.37	0	0	0	214359	221036	1	2	2	19	0	0	0	0	0	100	0	6	8	0	0	0	0	0	0
T1ND3	640766.2	0.03	4.37	0	0	0	214359	220918	2	4	3	40	0	0	0	0	0	100	0	6	8	0	0	0	0	0	0

T1ND4	653267.4	0.03	4.37	0	0	0	214359	220556	0	3	3	38	0	0	0	0	0	100	0	6	8	0	0	0	0	0	0
T1ND5	691277	0.03	4.37	0	0	0	214359	219595	2	4	3	45	0	0	0	0	0	100	0	6	10	0	0	0	0	0	0
T1ND6	1590785	0.03	4.37	0	0	67.32	214359	219776	0	2	2	24	0	0	0	0	2638	100	39	6	10	9	7	0	3	0	118
T1ND7	1749455	0.03	4.37	0	0	79.06	214359	219799	2	4	3	46	0	0	0	0	3108	103	37	6	14	15	4	0	4	0	147
T1ND8	1885120	0.03	4.37	0	0	88.43	214359	219383	1	3	2	31	0	0	0	0	3399	100	67	6	10	15	0	0	6	0	144
T1ND9	1966653	0.03	4.37	0	0	82.94	214359	216745	0	3	3	38	0	0	0	0	3269	100	44	6	45	13	5	0	6	0	148
T1ND10	2323172	0.03	4.37	0	0	83.19	214359	210052	2	4	3	44	0	0	0	0	3276	100	37	6	58	15	0	0	4	0	142
T1ND11	8316584	0.03	4.37	0	0	84.75	212379	124056	2	3	3	33	0	0	0	0	3167	100	204	17	3327	35	7	11	14	2	129
T1ND12	9184210	0.03	4.37	0	0	93.27	212379	109035	3	6	5	67	0	0	0	0	3555	100	204	17	3357	11	15	8	14	2	169
T1ND13	9638423	0.03	4.37	0	0	92.62	212379	109212	1	4	3	43	0	0	0	0	3603	100	86	17	3785	12	5	0	10	5	159
T1ND14	9742423	0.03	4.37	0	0	99.79	212379	108986	1	5	3	45	0	0	0	0	3777	100	117	17	3608	25	0	1	15	5	180
T1ND15	10876567	0.05	4.49	0	0	86.11	212379	94428	2	3	3	33	12	3	0	0	3442	100	86	17	3785	12	6	0	10	5	147
T1ND16	12856314	0.03	15.63	0	0	87.09	211389	67122	2	6	4	57	0	131	0	0	3370	117	164	17	3327	16	12	10	24	3	190
T1ND17	13018961	0.03	18.24	0	0	97.70	211389	66894	1	5	3	42	0	151	0	0	3716	103	188	17	3327	22	13	6	29	3	196
T1ND18	15996592	0.03	88.89	0	0	99.22	211389	47021	1	2	2	17	0	691	0	2	3762	110	144	17	3327	13	4	3	26	4	148
T1ND19	16187020	0.03	94.03	0	0	98.40	211389	46396	2	4	3	45	0	732	0	0	3744	100	154	17	3327	12	16	2	24	3	196
T1ND20	16345229	0.03	95.15	0	0	98.50	211389	44921	3	6	4	63	0	740	0	0	3745	100	154	17	3327	13	9	6	25	3	179
T1ND21	16391353	0.03	97.79	0	0	99.49	211389	44883	3	7	5	74	0	756	0	0	3769	122	154	17	3327	14	10	3	25	3	157
T1ND22	16551927	0.03	95.97	0	0	98.94	211389	43696	2	7	5	70	0	746	0	0	3756	100	154	17	3327	19	17	8	25	3	183
T1ND23	17690595	0.03	95.97	0	0	99.07	205719	38937	2	6	4	55	0	746	0	0	3759	105	164	26	3327	17	17	17	25	3	206
T1ND24	18556555	0.39	97.98	0	0	99.53	201939	35822	2	5	4	49	199	757	0	0	3770	139	147	40	3327	24	6	5	21	3	153
T1ND25	21116597	0.80	97.95	0	0	99.52	198429	18514	2	4	3	35	426	757	0	0	3770	100	154	40	3327	31	7	8	36	4	155
T1ND26	22033608	0.03	100	0	0	100	195948	18514	3	8	5	80	0	769	0	0	3782	534	218	40	3327	14	13	16	33	7	186
T1ND27	23676596	4.57	97.98	0	0	99.53	165708	34652	1	3	2	22	2520	757	0	1	3770	139	153	387	3327	27	12	12	16	3	153
T1ND28	26236588	10.63	97.95	0	0	99.52	164046	19973	3	5	4	56	5925	757	0	1	3770	116	151	381	3327	13	9	8	38	4	152
T1ND29	28796538	0.27	97.98	0	0	99.53	137229	18432	2	4	3	40	136	757	0	0	3770	136	150	381	3327	23	5	6	37	4	154
T1ND30	31356592	13.81	100	0	0	100	132816	18514	2	4	4	56	7757	769	0	0	3782	128	221	387	3604	12	7	18	39	7	168
T1ND31	33916600	8.54	97.03	0	0	99.31	103125	18514	3	6	4	62	4801	752	0	0	3765	102	152	387	3327	8	11	15	39	4	152

T1ND32	36476555	30.91	100	0	0	100	103125	21612	1	2	2	29	17399	769	0	0	3782	128	216	387	3608	16	11	15	33	6	174
T1ND33	39036546	59.75	97.79	0	0	99.49	103125	18514	4	6	5	68	33604	756	0	1	3769	122	184	387	3327	11	15	13	14	4	155
T1ND34	41596587	79.03	100	0	0	100	103125	18514	2	4	3	48	44425	769	0	0	3782	129	215	387	3608	17	11	12	25	7	168
T1ND35	46716592	99.15	96.53	0	3.25	99.15	77805	21552	3	6	5	66	55622	750	0	1857	3762	158	204	387	3357	28	12	22	36	4	221
T1ND36	49276587	99.42	97.51	0	4.50	99.42	77805	17262	3	5	4	61	55773	755	0	2551	3768	105	163	387	3817	27	33	19	38	6	254
T1ND37	51836540	94.38	95.86	0.01	66.11	96.72	77805	14809	3	5	5	71	52945	741	1	37147	3690	492	308	387	3640	13	8	69	40	7	289
T1ND38	59516530	82.62	81.04	6.91	66.75	87.58	54274	3066	2	5	5	68	46291	624	892	37378	3321	104	183	387	3327	5	4	56	52	7	232
T1ND39	62076526	91.11	91.86	47.73	82.32	92.02	46443	2483	3	5	5	72	51082	678	6167	46144	3517	113	192	387	3327	15	8	61	39	7	335
T1ND40	74876561	97.31	99.19	27.76	70.08	99.66	44608	2064	3	5	5	72	54589	761	3603	39346	3773	7956	1059	387	3607	68	117	54	41	9	336
T1ND41	1.52E+08	99.71	99.27	89.41	99.41	99.62	14486	772	4	8	6	92	55932	765	11556	55775	3773	462	1615	2775	11236	45	137	85	50	8	322
T1ND42	2.08E+08	100	100	97.44	100	100	0	1	3	7	6	87	56094	769	12601	56110	3782	654	724	2809	3770	188	94	185	118	47	1475
T1ND43	2.15E+08	100	100	99.99	100	100	0	21	3	5	5	71	56098	772	12936	56167	3809	667	772	2809	3777	279	213	340	156	61	3459
T1ND44	2.23E+08	100	100	100	100	100	0	0	3	7	6	87	56094	769	12930	56110	3782	706	722	2786	8550	129	91	205	123	50	1339

Finally, Table G.18 shows the metrics of the set of efficient points obtained from the response model applied to the real conditions of the flood of Villahermosa in 2007.

Table G.18. Metrics of the efficient points of the response model applied to a flood of 4 meters in Villahermosa

SOL	COST	FILL RATE					UNFULFILLMENT		AGENCIES (PER PERIOD)				PRODUCTS SUPPLIED					MAXIMUM PERSONNEL USED P/PERIOD				MAXIMUM NUMBER OF VEHICLES USED P/PERIOD)					
		FOOD	MED	CKIT	PKIT	HKIT	NVH	NVS	MAX	MIN	AVG	TOTAL	FOOD	MED	CKIT	PKIT	HKIT	PC	PD	PH	PS	S	M	L	B	H	TRIPS
T2ND1	10473088	0	1.94	0	0	0	426380	422526	4	4	4	64	0	0	0	0	0	570	58	16	182	8	0	0	6	3	0
T2ND2	10473088	0	1.94	0	0	0	424236	401598	4	4	4	64	0	0	0	0	0	388	0	16	182	0	0	0	0	0	0
T2ND3	10473088	0	1.94	0	0	0	424236	401551	4	4	4	64	0	0	0	0	0	388	0	16	182	0	0	0	0	0	0
T2ND4	10473088	0	1.94	0	0	0	424236	401550	4	4	4	64	0	0	0	0	0	388	5	16	182	1	0	0	0	0	0
T2ND5	10869217	0	1.94	0	0	93.49	424236	402825	4	4	4	64	0	0	0	0	1229	388	63	16	182	8	0	0	5	2	143
T2ND6	10876631	0	1.94	0	0	94.95	424236	402925	4	4	4	64	0	0	0	0	1249	403	67	16	182	8	0	0	5	3	148
T2ND7	11050224	0	1.94	0	0	95.34	424236	400395	5	4	5	65	0	0	0	0	1254	403	70	16	202	7	0	0	9	2	142
T2ND8	12983456	0	1.94	0	0	0	423268	357238	4	4	4	64	0	0	0	0	0	570	0	27	3451	0	0	0	0	0	0
T2ND9	15493825	0	1.94	0	0	0	422444	323862	4	4	4	64	0	0	0	0	0	553	0	17	3447	0	0	0	0	0	0

T2ND10	16142030	0	1.94	0	0	0	422272	312634	4	4	4	64	0	0	0	0	0	650	0	27	3451	0	0	0	0	0	0
T2ND11	18004193	0	1.94	0	0	0	422328	289778	4	4	4	64	0	0	0	0	0	388	0	17	3067	0	0	0	0	0	0
T2ND12	18234519	0	1.94	0	0	2.20	421706	256878	5	4	5	66	0	0	0	0	61	388	32	27	3451	4	0	0	5	1	39
T2ND13	18649480	0	1.94	0	0	98.48	421266	251746	6	4	5	78	0	0	0	0	1303	388	82	27	3469	11	0	0	5	3	150
T2ND14	19159757	0	1.94	0	0	53.19	421267	241105	8	4	6	92	0	0	0	0	654	388	42	27	3577	4	3	0	5	1	106
T2ND15	20514561	0	1.94	0	0	0	420450	211856	4	4	4	64	0	0	0	0	0	388	0	27	3451	0	0	0	0	0	0
T2ND16	23024930	0	1.94	0	0	0	419303	178803	4	4	4	64	0	0	0	0	0	570	34	27	3451	0	0	0	10	1	0
T2ND17	23198453	0	1.94	0	0	0.01	419558	167159	5	4	5	65	0	0	0	0	1	398	6	27	3535	0	0	0	2	1	1
T2ND18	24129096	0	1.94	0	0	15.57	419398	159863	6	4	5	72	0	0	0	0	356	475	96	27	3451	8	6	1	10	1	134
T2ND19	24512105	0	1.94	0	0	72.42	419286	146377	8	4	7	104	0	0	0	0	1009	388	82	27	3589	12	3	0	10	1	143
T2ND20	24858007	0	1.94	0	0	95.40	419286	143238	9	4	7	108	0	0	0	0	1266	403	98	27	3589	8	6	0	10	1	148
T2ND21	25221995	0	1.94	0	0	98.81	419286	139457	9	4	7	104	0	0	0	0	1303	418	89	27	3950	10	2	0	10	3	151
T2ND22	25795360	0	6.03	0	0	93.82	419293	140768	8	4	6	95	0	161	0	0	1223	388	64	27	4037	3	0	0	11	4	218
T2ND23	27202862	0	2.02	0	0	92.85	419366	123986	9	4	8	127	1	4	0	0	1216	465	69	27	4070	8	3	0	11	3	196
T2ND24	28226622	0	19.55	0	0	98.73	419288	121364	10	4	9	135	1	235	0	0	1306	576	82	27	4107	3	3	0	11	4	185
T2ND25	29131398	0	75.37	0	0	99.79	419286	123433	10	4	8	116	0	1030	0	0	1320	388	84	27	4114	10	1	0	11	4	286
T2ND26	30676661	0	78.25	0	0	99.35	419286	106218	10	4	8	119	0	1058	0	0	1315	388	69	27	4249	4	0	0	11	4	293
T2ND27	31543464	0	78.88	0	0	100	411996	105782	11	4	9	130	0	1062	0	0	1324	388	74	36	4249	5	0	0	11	4	303
T2ND28	42171199	0.11	77.09	0	0	97.89	338754	103133	13	6	10	157	119	1034	0	0	1292	546	71	387	4249	4	2	0	11	4	282
T2ND29	44567255	0	73.23	0	0	96.91	311479	102838	13	6	9	141	0	908	0	0	1255	403	65	397	4249	2	1	0	11	4	231
T2ND30	45392962	0	77.56	0	0	98.95	307523	103306	13	6	10	148	5	1048	0	0	1312	416	75	387	4249	4	1	0	11	4	297
T2ND31	47074368	0	78.46	0	0	96.52	312126	96080	13	6	10	146	0	1059	0	0	1278	671	153	397	4487	7	1	10	11	4	278
T2ND32	49792621	0	25.89	0	0	93.82	277113	99171	13	7	11	162	0	455	0	0	1243	495	415	397	4484	45	1	15	11	4	266
T2ND33	51212976	13.31	78.10	0	0	99.80	306533	97982	13	5	10	148	14767	1061	0	0	1320	507	99	397	4246	5	4	1	11	4	304
T2ND34	52654081	0	78.85	0	0	100	245070	104872	13	4	9	143	0	1064	0	0	1324	397	74	397	4249	5	0	0	11	4	304
T2ND35	57032990	0.05	77.74	0	0	99.31	251315	87032	13	5	9	138	50	1025	0	0	1315	430	70	387	4249	8	0	1	11	3	281
T2ND36	61116306	34.29	76.67	0	0	88.71	244390	99692	13	4	10	154	38515	1043	0	1	1193	435	258	397	4245	2	0	22	11	4	267
T2ND37	66547780	32.39	77.61	0	0	86.56	245380	73512	13	5	9	142	36306	1064	0	0	1180	1630	250	397	6967	15	6	11	10	3	292

T2ND38	67296097	52.70	78.23	0	0	99.34	243400	84480	13	4	9	140	59014	1064	0	0	1316	448	202	397	4487	8	2	16	15	4	317
T2ND39	73028428	88.21	77.80	0	0	98.81	243399	87317	14	4	9	140	98335	1064	0	0	1309	388	235	397	4234	9	4	11	11	4	416
T2ND40	73497575	93.31	77.96	0	0	97.43	243399	88045	14	4	9	143	103965	1064	0	0	1291	388	64	397	4230	3	0	0	11	4	513
T2ND41	75965583	99.69	78.19	0	0	99.30	242774	84147	14	4	9	144	111064	1064	0	0	1314	395	255	397	4487	6	0	19	11	4	437
T2ND42	85829707	99.54	78.52	0	72.67	98.68	241103	86809	14	4	10	155	110893	1064	0	80972	1304	491	424	397	4473	6	9	29	11	4	637
T2ND43	86132977	95.73	77.81	0	30.91	97.46	242822	57322	13	4	9	137	106679	1064	0	34558	1296	425	451	397	8682	5	5	38	16	4	481
T2ND44	87409376	99.30	78.53	0	73.06	97.92	222633	84048	14	5	10	151	110627	1064	0	81334	1295	539	420	397	4479	4	3	33	13	4	616
T2ND45	89002044	99.80	77.81	0	74.15	99.22	221938	76764	14	5	10	155	111190	1064	0	82643	1315	559	381	397	4487	5	7	26	11	4	606
T2ND46	93290439	96.89	77.74	0	74.89	86.56	223370	54560	14	4	9	142	107964	1064	0	83547	1181	412	439	397	8160	9	10	33	10	5	596
T2ND47	97772950	96.85	77.41	51.48	74.97	99.36	221689	45288	14	5	10	159	107921	1064	13270	83612	1317	2081	416	397	6580	30	4	37	11	4	624
T2ND48	1.15E+08	100	77.89	75.91	75.04	99.70	219936	14395	14	5	10	147	111411	1064	19578	83734	1320	2829	576	397	6580	5	8	48	11	3	607
T2ND49	1.21E+08	100	78.19	68.83	74.58	100	213213	2864	12	5	9	140	111411	1064	17746	83134	1324	449	464	397	8757	4	24	39	11	3	605
T2ND50	1.27E+08	100	77.98	4.98	74.88	100	177042	22759	13	6	10	157	111411	1064	1281	83571	1324	2568	622	2775	8444	10	7	49	21	3	642
T2ND51	1.33E+08	98.36	77.87	0.04	55.05	100	151189	19034	14	5	10	146	109590	1064	11	61447	1324	2340	580	2775	8685	4	9	48	11	3	531
T2ND52	1.39E+08	98.28	78.60	80.08	74.91	97.01	148843	16103	14	5	10	152	109505	1064	20649	83539	1286	1313	923	2771	8597	9	25	74	13	4	881
T2ND53	1.44E+08	99.44	78.59	77.31	75.08	98.57	144147	15221	14	5	10	159	110782	1064	19934	83768	1305	454	889	2775	8587	67	103	42	19	4	741
T2ND54	1.5E+08	100	77.74	77.05	75.07	99.82	145305	1751	12	5	9	142	111411	1064	19872	83760	1322	418	1192	2769	8159	42	104	49	17	3	569
T2ND55	1.66E+08	100	78.55	80.06	75.00	100	89920	15244	13	5	9	140	111411	1074	20649	83645	1324	1442	1502	2775	8668	58	105	47	19	3	637
T2ND56	1.73E+08	100	78.40	80.10	75.08	100	86189	13758	14	5	10	154	111411	1074	20649	83796	1324	545	1206	2769	7949	34	104	50	16	3	629
T2ND57	1.84E+08	99.92	79.19	80.08	74.98	100	84877	968	14	5	10	159	111326	1074	20649	83681	1324	6286	1040	2775	8755	2	118	28	12	4	657
T2ND58	1.91E+08	98.67	79.67	32.75	74.97	94.60	46607	22682	12	6	10	152	109930	1074	8458	83636	1253	1658	1301	2769	8705	4	103	57	16	3	595
T2ND59	1.97E+08	99.60	79.83	80.09	75.08	99.04	44345	19085	12	5	11	162	110961	1074	20649	83780	1311	2275	647	2780	12463	8	14	53	16	4	681
T2ND60	2.03E+08	95.00	71.06	53.38	73.09	86.47	41525	2303	12	5	9	142	105808	974	13754	81522	1154	2327	650	2775	8756	5	3	54	16	3	739
T2ND61	2.2E+08	100	78.63	79.96	74.95	100	34021	913	11	5	8	127	111411	1074	20618	83614	1324	2814	622	2769	11869	34	11	53	11	3	658
T2ND62	2.3E+08	100	78.96	80.06	75.16	100	31229	0	10	5	8	120	111411	1074	20649	83876	1324	3497	1064	2769	7923	45	103	50	26	5	638
T2ND63	2.36E+08	100	78.38	80.05	75.17	100	29153	0	11	5	8	119	111411	1074	20649	83876	1324	2402	1671	2769	7909	140	103	49	17	3	588
T2ND64	2.67E+08	98.05	78.34	6.50	72.73	99.65	12641	2461	11	4	8	120	109222	1072	1715	80965	1311	397	885	2779	10610	8	103	51	10	4	694
T2ND65	2.78E+08	100	79.11	80.07	75.00	100	6263	121	11	5	9	133	111411	1074	20649	83678	1324	2916	577	2792	8753	12	12	47	11	4	766

T2ND66	3.01E+08	100	78.61	71.35	74.91	100	0	72	10	5	8	113	111414	1074	18377	83583	1324	7418	1354	2796	8114	38	103	47	12	3	705
T2ND67	3.13E+08	100	78.90	80.07	75.19	100	0	0	11	6	8	121	111411	1074	20648	83866	1324	1370	1556	2791	10463	39	110	60	18	5	1882
T2ND68	3.47E+08	100	79.47	80.09	75.26	100	0	0	11	7	9	141	111411	1074	20649	83876	1324	846	1452	2790	12456	41	107	56	24	6	3099

Appendix H. Demand per period for the application of the response model in the three cases

Veracruz

Using the historic data provided by SSV (2014), the demand was projected to each one of the shelters selected considering expected demand and Table H.1 contains the results for the three scenarios in Veracruz

Table H.1. Demand per period for the three scenarios in Veracruz

	Shelter	Maximum Demand	T_0	T_1	T_2	T_3	T_4	T_5	T_6
Flood 0.5 m	4	83	73	65	14	35	62	53	11
	12	94	83	74	16	39	70	60	13
	13	98	86	77	17	41	73	62	13
	33	93	82	73	16	39	70	59	13
	35	888	777	694	148	368	660	562	117
	36	98	85	76	16	40	72	61	12
	39	396	346	309	66	164	294	250	52
		Total	1532	1368	293	726	1301	1107	231
Flood 1.5 m	3	1496	1310	1170	251	621	1112	946	198
	5	764	669	598	128	317	568	484	101
	6	800	701	626	134	332	595	506	106
	25	394	344	307	65	164	293	249	51
	27	798	698	623	133	330	593	504	105
	35	888	777	693	148	368	659	561	117

		Total	4499	4017	859	2132	3820	3250	678
Flood 2.5 m	3	1495	1309	1169	250	620	1111	945	198
	5	700	613	548	117	291	521	443	93
	8	197	173	154	33	82	147	125	26
	14	295	259	231	50	123	220	187	39
	15	396	347	310	67	165	295	251	53
	16	190	167	149	32	79	142	121	26
	18	395	346	309	67	164	294	250	53
	21	200	175	157	34	83	149	127	27
	24	691	604	541	116	287	513	437	91
	25	400	350	313	67	166	297	252	52
	26	296	259	231	49	123	219	187	39
	27	793	693	619	132	328	589	501	104
	28	496	434	387	82	205	368	313	65
	29	193	168	150	32	80	143	121	25
	30	200	175	156	33	82	148	126	26
	34	197	172	153	32	81	146	124	25
	35	886	775	692	148	367	658	560	116
	37	184	161	143	30	76	136	116	24
	39	396	346	309	66	164	294	250	52
		Total	7526	6721	1437	3566	6390	5436	1134

Acapulco

Using information about the evolution of demand over the entire flood, the demand per shelter per period was obtained as shown on Table H.2.

Table H.2. Demand per period over time for the three scenarios in Acapulco

Depth	**Shelter**	**Max Dem**	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
Flood 0.5 m	8	300	25	225	172	74	50	47	44	41	43	45	48	39	21
	18	195	16	145	111	47	31	31	28	26	27	29	30	24	13
	38	192	16	144	110	47	32	30	28	26	28	29	31	25	14
	45	600	50	450	344	147	99	94	86	82	86	90	95	77	42
	46	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	67	1000	82	748	572	244	164	156	144	136	142	150	158	128	69
	77	280	23	209	160	68	45	43	40	37	39	41	44	35	19
	81	500	41	374	286	122	81	77	72	67	70	74	78	63	34
	83	1100	90	823	630	269	180	171	158	148	155	165	172	139	76
	103	90	8	68	52	22	15	15	13	13	13	14	14	12	7
		Total	360	3261	2495	1065	714	680	628	590	618	652	686	555	302
Flood 1.5 m	9	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	11	300	25	225	172	74	50	47	44	41	43	45	48	39	21
	13	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	17	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	19	92	8	69	53	23	16	15	14	13	14	14	15	12	7
	20	60	5	45	35	15	10	10	9	9	9	9	10	8	5
	22	400	34	300	229	98	66	63	58	55	57	60	63	51	28
	23	192	16	144	110	47	32	30	28	26	28	29	31	25	14
	24	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	26	300	25	225	172	74	50	47	44	41	43	45	48	39	21
	32	75	7	57	43	19	13	12	11	11	11	12	12	10	6

	33	100	9	75	58	25	17	16	15	14	15	15	16	13	7
	40	368	31	276	211	90	61	58	54	50	53	55	58	47	26
	41	84	7	63	49	21	14	14	13	12	12	13	14	11	6
	43	400	34	300	229	98	66	63	58	55	56	60	63	51	28
	45	600	50	450	344	147	99	94	87	82	86	89	95	77	42
	47	300	25	225	172	74	50	47	44	40	43	44	48	39	21
	48	400	34	300	229	98	66	63	58	54	57	59	63	51	28
	50	100	8	75	58	25	16	16	14	14	14	14	16	13	7
	52	500	41	375	287	123	81	78	72	67	70	74	79	64	35
	54	1500	123	1123	859	367	245	234	216	202	212	224	236	191	103
	56	300	24	225	172	73	49	47	43	40	42	44	48	38	20
	58	300	24	225	172	73	49	46	43	40	42	44	47	38	20
	59	400	33	299	228	97	65	62	57	54	56	59	62	50	27
	62	88	7	65	50	21	14	13	12	11	12	13	13	11	7
	67	900	74	673	515	219	147	140	129	121	127	134	141	114	62
	68	400	33	299	228	97	65	62	57	54	56	60	62	50	27
	69	400	33	299	228	97	65	62	57	54	56	60	62	50	27
	71	300	24	224	171	73	49	46	43	40	42	45	47	38	20
	74	100	8	74	57	24	16	15	14	13	14	15	15	12	7
	80	200	16	149	114	48	32	31	28	27	28	30	31	25	13
	81	500	41	374	286	122	81	77	72	67	70	75	78	63	34
	82	60	4	44	34	14	10	10	9	9	9	9	10	8	5
	83	1100	90	823	629	268	180	171	158	148	155	165	172	139	76
	84	600	49	449	343	146	98	93	86	81	85	90	94	76	41
	88	198	16	148	113	48	32	30	28	26	28	30	31	25	14
	93	100	8	74	57	24	16	15	14	13	14	15	15	12	7
	94	255	21	190	145	62	41	39	36	34	36	39	40	32	18
	96	300	24	224	171	73	49	46	43	40	42	45	47	38	20

	99	100	8	74	57	24	16	15	14	13	14	15	15	12	7
	100	200	16	149	114	48	32	31	28	27	28	30	31	25	13
	103	90	7	67	51	21	14	14	12	12	12	14	14	12	7
		Total	1078	9775	7477	3190	2140	2036	1882	1766	1851	1952	2054	1661	905
Flood 2.5 m	3	150	13	113	86	37	22	23	22	21	22	23	24	20	11
	5	300	25	225	172	74	43	46	44	41	43	45	48	39	21
	6	400	33	300	229	98	57	61	58	55	57	60	63	51	28
	8	300	25	225	172	74	43	46	44	41	43	45	48	39	21
	9	150	13	113	86	37	22	23	22	21	22	23	24	20	11
	11	350	29	262	201	86	50	53	51	48	50	53	56	45	25
	12	350	29	262	201	86	50	53	51	48	50	53	56	45	25
	13	100	9	75	58	25	15	16	15	14	15	15	16	13	7
	14	100	9	75	58	25	15	16	15	14	15	15	16	13	7
	15	100	9	75	58	25	15	16	15	14	15	15	16	13	7
	16	80	7	60	46	20	12	13	12	11	12	12	13	11	6
	17	100	9	75	58	25	15	16	15	14	15	15	16	13	7
	18	195	17	146	112	48	28	30	29	27	28	30	31	25	14
	22	432	36	324	248	106	62	65	63	59	62	65	68	55	30
	23	192	16	144	110	47	28	29	28	26	28	29	31	25	14
	24	150	13	113	86	37	22	23	22	21	22	23	24	20	11
	28	260	22	195	149	64	38	40	38	36	37	39	41	34	19
	29	192	16	144	110	47	28	29	28	26	28	29	31	25	14
	31	100	9	75	58	25	15	16	15	14	15	15	16	13	7
	32	75	7	57	43	19	11	12	11	11	11	12	12	10	6
	33	120	10	90	69	30	18	19	18	17	18	18	19	16	9
	34	150	13	113	86	37	22	23	22	21	22	23	24	20	10
	36	300	25	225	172	74	43	46	44	41	43	45	48	39	20
	37	150	13	113	86	37	22	23	22	21	22	23	24	20	10

	38	192	16	144	110	47	28	29	28	26	28	29	31	25	14
	39	157	13	118	90	39	23	24	23	22	23	24	25	20	10
	40	400	33	300	229	98	57	61	58	55	57	60	63	51	28
	42	350	29	262	201	86	50	52	51	48	50	53	56	45	25
	43	400	33	300	229	98	57	60	58	55	57	60	63	51	28
	44	300	25	225	172	74	43	45	44	41	43	45	48	39	21
	45	600	50	450	344	147	86	90	87	82	86	90	95	77	42
	46	100	9	75	58	25	15	15	15	14	15	15	16	13	7
	47	300	25	225	172	74	43	45	44	41	43	45	48	39	21
	48	436	36	327	250	107	63	65	63	58	61	66	69	56	31
	50	144	12	108	83	36	21	21	21	19	20	22	23	19	10
	51	400	33	300	229	98	57	60	58	54	56	60	63	50	28
	52	500	42	375	287	123	72	75	73	67	70	75	79	64	35
	53	258	22	194	148	64	37	38	37	34	36	39	41	32	18
	54	1500	124	1123	859	367	214	225	216	202	212	225	235	190	104
	55	75	7	57	43	18	11	11	10	10	10	12	12	10	6
	56	372	31	278	213	90	53	55	53	50	52	56	58	47	26
	58	300	25	224	172	73	42	45	43	40	42	45	47	38	20
	59	400	33	299	229	97	56	60	57	54	56	60	62	50	27
	60	260	22	194	149	63	37	39	37	35	36	39	40	33	18
	61	174	14	130	100	42	24	26	25	23	24	27	27	22	12
	62	150	12	112	85	36	21	22	21	20	21	23	23	19	10
	64	350	28	261	200	85	49	52	50	47	49	53	55	44	24
	65	100	8	74	57	24	14	15	14	13	14	15	15	12	7
	67	1000	82	748	572	244	142	150	144	135	141	150	157	127	69
	68	400	32	299	228	97	56	60	57	54	56	59	62	50	27
	69	400	32	299	228	97	56	60	57	54	56	59	62	50	27
	70	360	29	269	206	87	51	54	51	48	51	53	56	45	24

	71	300	24	224	171	73	42	45	43	40	42	44	47	38	20
	72	96	7	71	54	23	13	14	13	12	13	14	15	12	7
	74	150	12	112	85	36	21	22	21	20	21	22	23	19	10
	77	280	23	209	160	68	39	42	40	37	39	41	44	35	19
	79	350	28	261	200	85	49	52	50	47	49	52	55	44	24
	80	250	20	187	143	61	35	37	36	33	35	37	39	31	17
	81	500	41	374	286	122	71	75	72	67	70	74	78	63	34
	83	1100	90	823	629	268	156	165	158	148	155	164	172	139	76
	84	600	49	449	343	146	85	90	86	81	85	89	94	76	41
	85	200	16	149	114	48	28	30	28	27	28	29	31	25	13
	86	76	6	56	43	18	10	11	10	10	10	11	11	10	6
	88	240	19	179	137	58	34	36	34	32	34	35	37	30	16
	89	100	8	74	57	24	14	15	14	13	14	14	15	12	7
	90	250	20	187	143	61	35	37	36	33	35	37	39	31	17
	91	100	8	74	57	24	14	15	14	13	14	14	15	12	7
	93	150	12	112	85	36	21	22	21	20	21	22	23	19	10
	94	255	21	190	145	62	36	38	36	34	36	38	40	32	17
	95	180	14	134	103	43	25	27	25	24	25	26	28	22	12
	96	300	24	224	171	73	42	45	43	40	42	44	47	38	20
	97	200	16	149	114	48	28	30	28	27	28	29	31	25	13
	98	100	8	74	57	24	14	15	14	13	14	14	15	12	7
	99	100	8	74	57	24	14	15	14	13	14	14	15	12	7
	100	200	16	149	114	48	28	30	28	27	28	29	31	25	13
	101	432	35	323	247	105	61	64	62	58	61	64	67	54	29
	103	90	7	67	51	21	12	13	12	12	12	13	14	11	7
		Total	1796	16294	12463	5318	3101	3276	3137	2944	3085	3254	3422	2769	1508

Villahermosa

Finally, Table H.3 contains the number of people sheltered per period on the city of Villahermosa for the three scenarios considered.

Table H.3. Demand per shelter per period in the flood of Villahermosa

FLOOD	ID	MAX DEMAND	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16
1 m	3	56	53	53	56	46	32	25	13	7	5	4	3	3	3	3	2	2	0
	4	500	467	467	494	404	283	217	115	62	40	31	23	20	26	24	18	12	8
	5	80	75	75	79	65	46	35	19	10	7	5	4	4	5	4	3	2	2
	6	172	161	161	170	139	98	75	40	22	14	11	8	7	9	9	6	4	3
	8	100	94	94	99	81	57	44	23	13	8	7	5	4	6	5	4	3	2
	11	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	12	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	13	200	187	187	198	162	113	87	46	25	16	13	9	8	11	10	7	5	3
	14	32	30	30	32	26	19	14	8	4	3	2	2	2	2	2	2	0	0
	19	97	91	91	96	79	55	43	23	12	8	6	5	4	5	5	4	3	2
	21	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	22	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	27	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	32	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	34	100	94	94	99	81	57	44	23	13	8	7	5	4	6	5	4	3	2
	35	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	36	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	38	200	187	187	198	162	113	87	46	25	16	13	9	8	10	10	7	5	3
	39	200	187	187	198	162	113	87	46	25	16	13	9	8	10	10	7	5	3
	43	500	467	467	494	404	283	217	115	62	40	31	23	20	25	24	18	12	8
	46	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	47	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	48	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2

	50	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	54	300	280	280	296	242	170	130	69	37	24	19	14	12	15	15	11	7	5
	55	700	654	654	691	565	395	304	161	86	56	43	31	27	35	34	25	16	11
	61	500	467	467	494	404	283	217	115	62	40	31	23	20	25	24	18	12	8
	63	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	64	400	374	374	395	323	226	174	92	50	32	25	18	16	20	19	14	9	6
	65	400	374	374	395	323	226	174	92	50	32	25	18	16	20	19	14	9	6
	66	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	69	100	94	94	99	81	57	44	23	13	8	7	5	4	5	5	4	3	2
	71	900	840	840	888	726	508	390	207	111	72	56	40	35	45	43	32	21	14
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	350	300	279	279	295	241	169	129	68	36	23	18	14	12	15	15	11	6	5
	351	200	186	186	197	161	112	86	45	24	15	12	8	8	10	10	7	4	2
	355	700	653	653	690	564	394	303	160	85	55	42	30	27	35	34	25	15	10
	363	300	279	279	295	241	169	129	68	36	23	18	14	12	15	14	11	6	5
	364	200	186	186	197	161	112	86	45	24	15	12	8	8	10	10	7	4	2
	369	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	370	300	279	279	295	241	169	129	68	36	23	18	14	12	15	15	11	6	5
	376	200	186	186	197	161	112	86	45	24	15	12	8	8	10	10	7	4	3
	378	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	381	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	391	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	394	300	279	279	295	241	169	129	68	36	23	18	14	12	15	15	11	6	5
	402	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	404	88	82	82	86	70	49	38	20	10	8	6	4	4	4	5	4	2	2
	408	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2

	411	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	419	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	424	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	425	72	67	67	71	58	40	31	16	9	6	5	4	3	3	4	3	2	2
	426	324	302	302	319	261	182	140	74	39	25	19	14	13	16	16	12	7	5
	428	79	73	73	77	63	44	34	18	10	7	5	4	4	3	4	3	2	2
	429	100	93	93	98	80	56	43	22	12	8	6	5	4	5	5	4	3	2
	442	1900	1773	1773	1874	1531	1071	822	435	232	152	116	84	73	95	90	67	42	28
	443	1000	933	933	986	806	564	433	229	122	80	61	45	39	50	48	35	22	15
		TOTAL	46194	46194	48836	39898	27928	21435	11351	6068	3959	3036	2188	1885	2495	2336	1721	1105	721
4 m	3	332	310	310	328	268	188	144	77	41	27	21	15	13	17	16	12	8	5
	4	2300	2147	2147	2270	1854	1298	996	528	282	184	142	101	88	115	108	79	51	34
	5	400	374	374	395	323	226	174	92	50	32	25	18	16	21	19	14	9	6
	6	856	799	799	845	690	483	371	197	105	69	53	38	33	44	40	30	19	13
	7	600	560	560	592	484	339	260	138	74	48	37	27	23	30	29	21	14	9
	8	200	187	187	198	162	113	87	46	25	16	13	9	8	11	10	7	5	3
	10	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	11	2004	1871	1871	1978	1616	1131	868	460	246	160	122	88	77	100	94	69	44	30
	12	1512	1412	1412	1492	1219	854	655	347	186	120	93	67	58	76	71	52	33	23
	13	800	747	747	790	645	452	347	184	99	64	50	36	31	40	37	28	17	12
	14	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	19	252	236	236	249	204	143	110	58	31	21	16	12	10	12	12	9	6	4
	21	1700	1587	1587	1678	1371	960	737	390	209	136	104	75	65	86	80	59	37	25
	22	1700	1587	1587	1678	1371	960	737	390	209	136	104	75	65	86	80	59	37	25
	27	1027	959	959	1014	828	580	445	236	126	83	63	46	40	52	48	35	22	15
	30	52	49	49	52	42	30	23	12	7	5	4	3	2	3	3	2	2	0
	31	156	146	146	154	126	89	68	36	20	13	10	7	6	8	8	6	4	3
	34	272	254	254	269	220	154	118	63	34	22	17	13	11	14	13	10	7	4

	35	2073	1935	1935	2046	1671	1170	898	476	255	166	128	91	79	104	97	72	46	31
	36	600	560	560	592	484	339	260	138	74	48	37	27	23	30	29	20	13	9
	37	600	560	560	592	484	339	260	138	74	48	37	27	23	30	29	20	13	9
	38	600	560	560	592	484	339	260	138	74	48	37	27	23	30	29	20	13	9
	39	848	792	792	837	684	479	368	195	104	68	53	38	33	43	40	30	19	13
	43	1787	1668	1668	1764	1441	1009	774	410	220	143	110	79	69	91	84	62	39	27
	45	7600	7093	7093	7498	6126	4288	3291	1743	932	608	466	335	290	382	359	264	169	111
	46	440	411	411	435	355	249	191	101	54	36	27	20	17	23	21	16	10	7
	47	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	48	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	50	600	560	560	592	484	339	260	138	74	48	37	27	23	30	29	20	14	9
	53	75	70	70	74	61	43	33	18	10	6	5	4	3	4	4	3	2	0
	54	700	654	654	691	565	395	304	161	86	56	43	30	26	36	34	24	16	11
	55	3800	3547	3547	3749	3063	2144	1646	872	466	304	233	167	144	192	180	132	84	56
	56	700	654	654	691	565	395	304	161	86	56	43	30	27	36	34	24	16	11
	57	243	227	227	240	196	138	106	56	30	20	15	11	10	13	12	9	6	4
	59	166	155	155	164	134	94	72	39	21	14	11	8	7	9	8	6	4	3
	63	272	254	254	269	220	154	118	63	33	22	17	13	11	14	12	10	7	4
	64	1384	1292	1292	1366	1116	781	600	318	170	110	85	62	53	70	66	48	30	21
	65	1954	1824	1824	1928	1575	1103	847	449	240	156	120	87	75	98	92	68	43	29
	66	596	557	557	588	481	337	259	137	74	48	37	27	23	30	28	20	14	9
	68	237	222	222	234	192	134	103	55	30	19	15	11	10	12	12	9	6	4
	69	200	187	187	198	162	113	87	46	25	16	13	9	8	11	10	7	5	3
	71	2948	2752	2752	2909	2377	1664	1277	676	362	235	180	130	112	148	140	103	65	43
	73	724	676	676	715	584	409	314	167	89	58	45	32	28	37	35	26	16	11
	76	238	223	223	235	192	135	104	55	30	20	15	11	10	12	12	9	6	4
	77	268	251	251	265	217	152	117	62	33	22	17	12	11	14	13	10	6	4
	81	1500	1400	1400	1480	1210	847	650	344	184	120	92	67	58	76	71	53	33	22

	86	362	338	338	358	292	205	157	84	45	29	23	16	14	19	18	13	9	6
	88	268	251	251	265	217	152	117	62	33	22	17	12	11	14	13	10	6	4
	91	800	747	747	790	645	452	347	184	99	64	50	36	30	40	38	28	18	12
	92	1741	1625	1625	1718	1404	983	754	400	214	140	106	77	67	88	83	61	38	26
	94	1495	1396	1396	1475	1205	844	648	343	184	120	92	67	57	76	71	52	33	22
	96	1195	1116	1116	1179	964	675	518	275	147	96	74	53	46	60	57	42	26	18
	99	200	187	187	198	162	113	87	46	25	16	12	9	8	11	10	7	5	3
	102	779	727	727	769	628	440	338	179	96	63	48	35	30	40	37	28	18	12
	108	375	350	350	370	303	212	163	86	46	30	22	17	15	19	18	14	9	6
	110	135	126	126	134	109	77	59	31	17	11	9	6	6	7	7	5	4	0
	113	147	138	138	146	119	83	64	34	19	12	10	7	6	8	7	6	4	3
	114	129	121	121	128	104	73	56	30	16	11	8	6	5	7	7	5	3	0
	116	122	114	114	121	99	69	53	28	15	10	8	6	5	7	6	5	3	0
	120	100	94	94	99	81	57	44	23	13	8	7	5	4	6	5	4	3	0
	128	100	94	94	99	81	57	44	23	13	8	7	5	4	6	5	4	3	0
	129	800	747	747	790	645	452	347	184	99	64	50	36	31	40	38	28	18	12
	134	255	238	238	252	206	144	111	59	32	21	16	12	10	13	13	9	6	4
	135	761	711	711	751	614	430	330	175	94	61	46	34	29	38	36	27	16	12
	138	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	142	500	467	467	494	404	283	217	115	62	40	31	23	20	26	24	18	12	8
	146	300	280	280	296	242	170	130	69	37	24	19	14	12	16	15	11	7	5
	147	592	553	553	585	478	335	257	136	73	48	37	27	23	30	28	21	14	9
	162	180	168	168	178	146	102	78	42	23	15	12	8	7	10	9	7	5	3
	167	365	341	341	361	295	206	159	84	45	30	23	17	14	19	18	13	9	6
	168	241	225	225	238	195	136	105	56	30	20	15	11	10	13	12	9	6	4
	169	155	145	145	153	125	87	68	36	19	13	10	7	6	8	8	6	4	3
	171	300	280	280	296	242	169	130	69	36	24	18	13	11	15	14	10	7	5
	172	237	222	222	234	192	133	103	55	29	19	14	10	9	11	11	8	6	4

	190	231	216	216	228	187	130	101	53	28	19	14	10	8	11	10	8	6	4
	191	423	395	395	418	341	238	184	97	51	34	25	18	16	21	19	14	9	7
	192	388	363	363	383	313	218	169	89	47	32	23	17	14	19	18	13	8	6
	194	400	374	374	395	323	225	174	92	49	32	24	17	15	20	18	13	8	6
	196	1996	1863	1863	1970	1609	1126	865	458	244	160	122	88	75	100	94	69	44	29
	198	300	280	280	296	242	169	130	69	36	24	18	13	11	15	14	10	7	5
	201	200	187	187	198	162	112	87	46	24	16	12	9	8	10	9	7	4	3
	202	400	374	374	395	322	225	173	92	49	32	24	17	15	20	18	13	8	6
	203	167	156	156	165	134	94	72	38	20	14	10	8	6	8	8	6	4	3
	207	700	654	654	691	564	394	303	160	85	56	42	30	26	35	33	24	15	10
	210	200	187	187	198	161	112	86	45	24	16	12	8	8	10	9	7	4	3
	212	900	840	840	888	725	507	389	206	110	72	55	39	34	45	42	31	20	13
	213	676	630	630	667	544	381	292	155	82	55	41	29	25	34	31	23	15	10
	214	100	93	93	98	80	56	43	22	12	8	7	4	4	6	4	4	3	0
	216	172	160	160	169	138	97	74	39	21	14	10	8	6	8	8	6	4	3
	217	66	61	61	65	53	37	28	15	9	6	5	3	3	4	4	3	2	0
	220	280	261	261	276	225	157	121	64	34	23	17	12	10	14	13	9	7	5
	222	400	373	373	394	322	225	173	91	49	32	24	17	15	20	18	13	8	6
	223	337	314	314	332	271	190	145	77	41	27	20	14	12	16	15	11	8	5
	224	159	148	148	156	128	89	68	36	19	13	10	8	6	8	8	6	4	3
	226	264	246	246	260	212	148	114	60	32	22	16	11	10	13	12	9	6	4
	227	600	559	559	591	483	338	259	137	73	48	36	26	22	30	28	20	13	9
	228	1600	1493	1493	1578	1289	902	692	366	196	128	98	70	60	80	75	55	35	23
	229	300	279	279	295	241	169	129	68	36	24	18	13	11	15	14	10	7	5
	231	2486	2319	2319	2452	2003	1402	1076	570	304	199	152	109	94	125	117	86	55	36
	236	256	238	238	252	206	144	110	58	31	21	15	11	9	12	12	8	6	4
	240	300	279	279	295	241	169	129	68	36	23	18	13	11	15	14	10	7	5
	242	176	164	164	173	141	99	76	40	21	14	10	8	6	8	8	7	4	3

	244	272	253	253	268	219	153	117	62	33	21	16	12	10	13	12	9	6	4
	245	90	83	83	88	72	50	38	20	11	8	6	4	4	4	4	4	3	0
	250	127	118	118	125	102	71	54	29	15	10	8	6	4	6	6	4	3	0
	251	1059	988	988	1044	853	597	458	242	129	84	64	46	40	53	49	36	23	15
	258	300	279	279	295	241	169	129	68	36	23	18	13	11	15	14	10	6	5
	260	562	524	524	554	452	317	243	128	68	44	34	24	21	28	26	19	12	8
	273	1358	1267	1267	1339	1094	766	588	311	166	108	83	60	51	68	64	47	30	19
	278	168	156	156	165	135	94	72	38	20	13	10	8	6	8	8	6	4	3
	280	164	153	153	161	132	92	71	37	20	13	10	8	6	8	8	6	4	3
	281	387	361	361	381	311	218	167	88	47	30	23	17	14	19	18	13	8	6
	282	96	89	89	94	77	54	41	22	11	8	6	4	4	4	4	4	3	0
	289	500	466	466	493	403	282	216	114	61	39	30	22	19	25	23	17	11	8
	290	162	151	151	159	130	91	70	37	19	12	10	8	6	8	8	6	4	3
	291	583	544	544	575	469	328	252	133	71	46	35	25	22	29	27	20	13	8
	292	644	600	600	635	519	363	278	147	78	51	39	28	24	32	30	22	14	9
	294	297	277	277	293	239	167	128	68	36	23	18	13	11	14	14	10	6	4
	300	204	190	190	201	164	115	88	46	25	16	12	9	8	10	9	8	4	3
	305	157	146	146	154	126	88	67	36	19	12	10	6	5	8	8	6	4	3
	311	192	179	179	189	154	108	83	44	23	15	11	8	7	10	9	7	4	3
	312	32	29	29	31	25	18	13	8	4	3	2	2	2	2	2	2	0	0
	316	300	279	279	295	241	169	129	68	36	23	18	13	11	15	14	10	6	4
	318	100	93	93	98	80	56	43	22	12	8	6	4	4	6	4	4	3	0
	319	60	55	55	59	48	33	25	13	8	5	4	3	3	4	3	3	2	0
	320	258	240	240	254	207	145	111	59	31	20	15	11	9	13	12	8	6	4
	324	288	268	268	284	232	162	124	66	35	23	17	12	10	14	13	10	6	4
	326	874	815	815	862	704	493	378	200	107	69	53	38	33	44	41	30	19	12
	329	1096	1022	1022	1081	883	618	474	251	134	87	67	48	41	55	51	38	24	15
	330	400	373	373	394	322	225	173	91	49	31	24	17	15	20	18	13	8	6

	334	131	122	122	129	105	73	56	30	16	10	9	5	4	6	7	4	3	0
	340	316	294	294	311	254	178	136	72	38	25	19	13	12	15	14	10	7	4
	341	581	542	542	573	468	327	251	133	71	46	35	25	22	29	27	20	12	8
	342	4400	4106	4106	4340	3546	2482	1905	1008	539	351	269	194	167	221	207	152	98	64
	349	992	925	925	978	799	559	429	227	121	79	60	43	37	49	46	34	22	14
	350	696	649	649	686	560	392	301	159	85	55	42	30	26	35	32	24	15	10
	363	788	735	735	777	635	444	341	180	96	63	48	34	29	39	37	27	17	11
	369	167	155	155	164	134	94	72	38	20	13	10	8	6	8	8	6	4	0
	372	679	633	633	669	547	383	294	155	83	54	41	30	25	34	32	23	15	9
	376	371	346	346	366	299	209	160	85	45	29	22	16	14	18	17	12	8	5
	378	300	279	279	295	241	169	129	68	36	23	18	13	11	15	14	10	6	4
	381	294	274	274	290	236	165	127	67	36	23	18	12	11	14	13	10	6	4
	391	284	265	265	280	228	160	122	65	34	22	17	12	10	14	13	9	6	4
	402	100	93	93	98	80	56	43	22	12	8	7	4	4	6	4	4	3	0
	408	100	93	93	98	80	56	43	22	12	8	7	4	4	6	4	4	3	0
	415	16	14	14	15	12	9	6	4	2	2	0	0	0	0	0	0	0	0
	419	139	129	129	137	112	78	60	31	17	11	9	6	5	8	7	4	4	0
	424	176	164	164	173	141	99	76	40	21	14	10	8	6	8	8	7	4	0
	426	886	826	826	874	714	499	383	203	108	70	54	39	33	44	41	30	19	12
	428	79	73	73	77	63	44	34	18	9	6	5	4	3	4	4	3	2	0
	439	568	530	530	560	457	320	245	130	69	45	34	25	21	28	26	19	12	8
	443	2280	2127	2127	2249	1837	1286	987	522	279	182	139	100	86	114	107	79	50	33
		TOTAL	92388	92388	97671	79795	55855	42869	22701	12136	7918	6071	4375	3769	4989	4671	3441	2210	1442

Appendix I. Relief from non-governmental organisations provided for the flood of Villahermosa

The magnitude of the flood in Villahermosa created the need to count with support from different organisations. After searching for information about the contributions from different agencies, the information was included in the response optimisation model. Table I.1 displays the donations from foreign countries considered for the analysis based on the selection of products used for this research.

Table I.1. International aid provided to the Mexican government for the flood of 2007

ID	Country	Type	Organisation	Description	Quantity	Unit	Tons	Date
ES001	Germany	ONG	Ministerio de ayuda Cristiana Negemias A.C.	Medicines	1	tons	1	19/11/2007
ES001	Germany	ONG	Ministerio de ayuda Cristiana Negemias A.C.	Water and food	0.18	tons	0.18	21/11/2007
ES003	Germany	Government	Government	Food, diapers, feminine towels, blankets	2	trailers	-	11/11/2007
ES010	Canada	ONG	Cien mujeres Mexicanas	Diapers	30	Boxes	0.201	27/11/2007
ES010	Canada	ONG	Cien mujeres Mexicanas	Feminine hygine towels	54	Boxes	0.135	27/11/2007
ES010	Canada	ONG	Cien mujeres Mexicanas	Blankets	150	items	0.45	27/11/2007
ES012	Chile	Government	Government	Medicines	21	boxes	0.75	14/11/2007
ES012	Chile	Government	Government	417 bags of toilet paper	1.668	tons	1.668	14/11/2007
ES012	Chile	Government	Government	150 boxes with napkins	0.8	tons	0.8	14/11/2007
ES012	Chile	Government	Government	15000 diapers	0.8	tons	0.8	14/11/2007
ES014	Cuba	Government	Government	Food and water	0.61	tons	0.61	08/11/2007
ES014	Cuba	Government	Government	Medicines	2.062	tons	2.062	08/11/2007
ES014	Cuba	Government	Government	Infermary supplies	0.03	Tons	0.03	08/11/2007
ES017	Spain	Government	Government	Blankets	16	Boxes	0.378	10/11/2007
ES017	Spain	Government	Government	Medicines	2	tons	2.5	10/11/2007
ES022	United States of America	ONG	Casas Puebla y Durango de los Ángeles and organisations from Orange county	Water and food	80	Boxes	-	08/11/2007
ES024	United States of America		Consulmex Sacramento	Water and food	59	Boxes	-	08/11/2007
ES024	United States of America		Consulmex Sacramento	Water and food	70	Boxes	-	08/11/2007
ES026	United States of America	Government	California Government	Food	70	lotes	33.075	10/11/2007
ES027	United States of America	ONG	Heart to Heart	Medicines	5111	lbs	2.3	19/11/2007

ES032	United States of America	Private	Gigante USA	Pantries with beans, rice and oil	3300	piece		20/11/2007
ES035	United States of America	Private	Sra. Laura Herrera	Clothes., shoes and food	20	tons	20	-
ES046	Honduras	Government	Government	Medicines	10	tons	10	14/11/2007
ES046	Honduras	Government	Government	Hygiene products, water, clothes and shoes, toys	2	tons	2	14/11/2007
ES046	Honduras	ONG	Comunidad de Mexicanos	Food	4620	lbs	2.079	22/11/2007
ES046	Honduras	Government	Government	Food	16380	lbs	2.371	22/11/2007
ES048	Israel	Government	Government	Diapers, sardines, sugar, beans, toilet paper, blankets, milk	-	-	-	24/11/2007
ES049	Israel	Private	Farmacéutica "Teva México"	Medicines	90	Boxes	-	25/11/2007
ES050	Japan	Government	Government	Blankets	700	Pieces	1.75	13/11/2007
ES053	Organisation	Organisation	PMA	Food	100	tons	100	09/11/2007
ES056	Panamá	ONG	Comunidad Mexicana en Panamá	Water, juices, toilet paper, diapers, cleaning items, instant soups, detergent	1.34	tons	1.34	29/11/2007
ES057	Perú	Government	Government	Medicines	64000	pills	0.9	08/11/2007
	Included							
	Not for distribution							
	Not useful alone							
	Too many products							

APPENDIX J. PHOTOGRAPHS OF THE FLOODS IN THE THREE REGIONS OF MEXICO

Veracruz

Aston University

Illustration removed for copyright restrictions

Source: Candelario (2010)

Figure J.1. Images obtained from the flood in Veracruz City

It is important to mention that not all of the images obtained were showing the flood, thus only a handful are included. Figure F.2 shows some of the images obtained in the area of Boca del Río.

Aston University

Illustration removed for copyright restrictions

Source: Manzur (2010)

Figure J.2. Images obtained from the flood in Boca del Río

Aston University

Illustration removed for copyright restrictions

Source: Shelterbox (2010)

Figure J.3. Images obtained from the flood in Veracruz and Boca del Río

Afterwards, through a search in Google® we were able to obtain some identifiable pictures located using the "Street View" in Google Maps® and shown on Figure J.4. It is noticeable that the southwest area was considerably affected by the flood, mostly in Boca del Rio. Therefore it can be said that the image provided by authorities is not delivering a reliable picture of the actual flood in the area. It can be seen that the image seem consistent with several of the pictures, including the area of la Floresta (southwest), the distributor road (south) and the market (southeast). It is also important to mention that in the GIS result there is damage near the school "Rafael Diaz Serdan", however the exact location is not accounted as flooded.

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Illustration removed for copyright restrictions

Source: Compiled by author with information from Veracruz_Antiguo (2010) and (Mexicanas_en_Noruega, 2010)

Figure J.4. Damage of the flood of 2010 in the region Veracruz-Boca del Río

Therefore, the assessment of the flood map obtained for the case of Veracruz was performed using satellite images as shown on Section 7.1.1.

Acapulco

The impact of the flood of 2013 in Acapulco from the flood mask provided by governmental authorities exhibited a very low level of damage, contradicting again reports from government itself about the extent of damage and people affected. Therefore a search for images was performed starting with the results shown on Figure F.5 on Flickr®, with a query of “floods” and “inundación” for pictures taken between September 17th and November 26th of 2013 in the map, and displaying only images that were in fact about the flood and disregarding the others.

Aston University

Illustration removed for copyright restrictions

Source: Flickr (2015) with information from Martínez (2015) and Herrera (2015)

Figure J.5. Images obtained from Flickr® of the flood in Acapulco in 2013

Based on the results, a search on Google® locating the images with Google Maps® provided the images shown on Figure F.6. According to the Figure the airport (lower right corner), the Acapulco Diamante area (next to the airport on the left), Llano Largo (on the lower orange area), and Pie de la Cuesta (on the upper left of the image) were flooded.

Aston University

Illustration removed for copyright restrictions

Source: Compiled by author with information from Excelsior (2013) and R3.0 (2013)

Figure J.6. Damage of the flood of 2013 in Acapulco

As a result, further analysis on the area was performed on section 7.1.2 using an infrared image of the flood.

APPENDIX K. RESULTS FROM THE ITERATIONS FOR INDEPENDENT AGENCIES IN PREPAREDNESS ACTIVITIES

Veracruz

A total of nine models were run to obtain the optimal solution for independent operation from the different agencies involved in the disaster. Table K.1 shows the non-dominated points for each one of the agencies.

Table K.1. Set of efficient points obtained from the application of the preparedness model to the nine agencies in Veracruz

DICONSA		DIF		IMSS		PC		SMEX		SVER		SEDENA		SEGOB		SEMAR	
COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)	COST	UFR (%)
1301915	90.69	1326090	91.33	1897537	51.19	1300352	93.84	1219859	97.14	3934356	33.03	1677031	65.74	1219994	97.15	1400694	83.75
1355366	86.58	1372162	88.03	1943318	47.12	1345830	90.49	1266816	94.48	3979753	32.37	1720766	63.78	1266801	94.48	1447887	80.37
1408739	82.98	1419156	84.83	1991396	45.29	1393231	87.12	1313065	91.14	4022174	31.97	1766586	61.9	1312703	91.16	1493584	77.45
1459855	80.77	1463871	82.33	2040989	43.69	1440476	84.04	1359722	88.29	4073864	31.06	1819347	59.35	1359991	88.72	1540903	74.76
1510701	77	1511856	79.44	2088294	41.94	1486413	81.58	1406627	84.63	4120835	28.7	1863832	58.18	1406627	84.63	1587611	72.39
1561446	74.56	1558351	76.7	2136478	40.85	1533446	78.76	1453177	82.52	4164276	28.16	1913363	55.54	1452285	82.55	1633389	70.12
1611868	71.13	1601644	74.32	2184549	39.33	1579867	76.18	1499043	79.56	4213257	27.29	1954557	53.61	1499043	79.56	1680784	67.91
1661396	68.58	1651786	72.07	2229635	38.27	1625463	74.49	1546248	77.16	4258774	26.28	2005980	52.28	1546104	77.39	1726766	65.82
1713783	65.95	1694718	70.14	2279196	36.95	1671624	71.99	1592669	74.77	4307118	25.3	2051540	50.38	1592457	74.99	1774081	63.89
1764630	64.26	1743289	68.18	2327511	35.69	1718345	70.05	1638804	72.67	4351790	24.71	2100215	48.95	1638467	72.75	1820664	62.08
1815166	61.45	1789232	66.03	2372641	34.8	1765378	67.75	1686122	70.88	4400150	24.33	2141919	47.73	1686065	71.14	1867247	60.81
1862848	59.9	1837604	64.51	2421991	33.85	1812969	66.21	1732779	68.92	4444224	23.78	2193194	46.51	1732837	68.92	1912945	58.79
1917079	57.91	1880863	62.73	2468157	32.92	1857438	64.68	1779294	67.15	4493647	23.06	2239924	45.05	1778712	67.32	1958272	57.28
1967918	56.75	1926046	61.3	2515287	32.16	1903433	62.96	1826036	65.47	4540288	22.54	2277388	44.46	1822814	65.7	2006760	55.83
2018624	55.02	1977399	59.99	2566597	31.4	1952555	61.5	1871364	64.14	4586506	22.22	2332340	43.18	1871918	64.09	2052317	54.57
2069537	53.28	2023595	58.73	2614770	31	1998933	60.25	1918483	62.57	4631441	21.59	2379306	42.13	1918529	62.65	2097151	53.45
2120376	51.75	2069780	57	2658361	29.79	2045264	59.07	1965215	61.22	4679672	21.17	2426535	41.32	1965881	61.27	2145873	52.04
2171170	51.1	2111628	55.84	2706859	28.81	2092142	57.62	2012234	59.82	4725202	20.89	2471295	40.62	2011983	59.88	2191907	50.83
2218434	50.12	2160364	55.03	2756458	28.09	2138627	56.23	2057975	58.82	4771141	20.56	2518362	39.78	2058888	58.82	2239786	49.65

2270213	48.41	2209232	53.9	2804607	27.43	2185768	55.27	2104358	57.35	4812382	20.15	2565600	38.83	2104358	57.35	2286387	48.54
2373768	47.91	2255525	52.87	2852327	26.86	2231732	54.36	2151600	56.16	4861437	19.75	2612493	38.19	2150745	56.27	2331561	47.57
2425178	45.8	2301890	51.66	2901555	26.24	2275522	53.36	2198697	55.33	4911996	19.41	2658032	37.41	2198697	55.33	2372021	46.81
2475931	44.11	2345367	51.04	2942107	25.85	2323642	52.33	2245112	54.41	4954778	19.1	2705377	36.73	2244092	54.35	2423940	46.18
2523321	43.13	2394070	49.48	2996832	25.12	2365523	51.28	2292087	53.33	4996877	18.8	2750824	36.41	2290978	53.33	2470183	44.78
2577515	41.41	2486537	48.27	3044816	24.61	2465275	50	2338425	52.21	5051494	18.79	2845868	36.06	2338183	52.25	2518738	43.53
2623520	40.57	2531338	46.81	3092603	24.19	2512361	48.29	2382922	51.28	5098858	18.4	2891725	34.59	2384859	51.35	2564593	42.71
2679171	40.03	2581140	45.42	3139909	23.73	2558505	47.36	2431717	50.46	5144666	17.95	2938096	33.76	2431573	50.47	2611880	41.85
2729951	38.89	2628008	44.34	3187784	23.24	2604926	45.94	2478122	49.47	5189329	17.25	2985730	33.03	2478229	49.48	2656604	41.21
2780675	37.5	2672882	43.51	3233110	22.79	2651105	44.68	2525061	48.93	5237535	16.86	3026288	32.12	2524797	48.81	2701450	40.37
2831191	36.65	2720893	42.79	3283697	22.46	2698098	43.92	2571380	47.67	5284915	16.47	3075579	31.27	2569901	47.72	2752389	39.66
2879678	36.18	2766918	42.15	3327496	22.07	2744519	43.08	2618172	46.32	5328965	15.99	3125256	30.57	2615313	46.43	2797823	39.04
2928335	35.29	2814028	41.52	3375400	21.6	2789907	42.48	2664491	45.29	5378255	15.61	3167045	29.9	2664206	45.3	2845460	38.25
2979014	34.78	2859680	40.5	3416725	21.34	2834120	41.91	2709325	44.4	5423644	15.34	3211438	29.38	2709325	44.4	2891905	37.58
3034793	34.16	2901095	39.98	3474571	21.06	2883174	41.21	2753963	43.52	5471544	15.12	3263302	29.02	2757008	43.52	2935955	36.97
3085168	33.43	2949982	39.38	3520131	20.68	2929433	40.35	2799869	42.91	5514081	14.87	3309756	28.45	2802822	42.95	2985010	36.29
3136374	33.25	2999922	38.86	3554519	20.27	2976773	39.94	2848992	42.24	5563243	14.66	3353604	28.21	2848924	42.4	3029893	35.75
3186524	32.45	3045822	38.22	3618123	19.91	3022403	39.31	2897486	41.78	5608717	14.51	3404224	27.76	2897832	41.78	3078350	35.19
3235595	31.86	3091005	37.54	3666235	19.67	3071525	38.69	2943913	41.06	5652767	14.35	3451882	27.17	2943459	41.03	3122887	34.72
3288740	31.3	3139141	37.16	3712891	19.39	3117039	38.14	2991017	40.29	5699187	14.19	3495831	26.86	2991017	40.29	3170714	34.21
3335578	30.98	3185926	36.65	3757522	19.18	3163141	37.65	3035066	39.8	5749385	14.02	3544977	26.58	3036530	39.77	3216390	33.76
3390267	30.72	3231734	36.24	3804935	18.88	3208193	37.16	3084045	39.35	5772689	13.81	3589744	26.28	3084045	39.35	3263886	33.23
3433123	30.39	3276996	35.8	3855273	18.52	3257894	36.64	3129148	38.83	5816738	13.64	3638150	25.91	3128330	38.84	3309881	32.71
3489581	30.24	3314924	35.39	3901992	18.36	3304241	36.32	3177385	38.27	5891704	13.5	3669552	25.73	3177385	38.27	3358354	32.32
3527908	29.71	3371137	34.83	3946279	18.17	3350319	35.9	3224035	37.81	5923174	13.49	3730323	25.32	3224069	37.81	3404113	32
3587159	29.29	3417702	34.51	3999419	17.87	3396935	35.63	3269810	37.35	5984129	13.47	3778083	25.15	3269810	37.35	3450779	31.65
3642292	28.97	3459274	34.18	4022026	17.61	3433646	35.19	3317067	37.01			3858423	24.85	3317067	37.01	3498238	31.44
3695149	28.94	3503795	33.93	4094315	17.57	3490288	34.83	3363683	36.68			3900926	24.77	3363650	36.69	3544181	31.22

3745049	28.91	3558105	33.72	4136043	17.27	3536390	34.54	3410334	36.36			3955130	24.71	3410334	36.36	3589510	31.06
3774970	28.76	3600501	33.53			3574874	34.38	3456083	36.1					3456083	36.1	3637052	30.85
								3494365	35.93					3494365	35.93	3672911	30.75

Acapulco

Also the case of Acapulco was explores allowing agencies to seek to relief the situation independently. The results obtained are shown on Table K.2.

Table K.2. Set of efficient points obtained from the application of the preparedness model to the ten agencies in Acapulco

DICONSA		**DIF**		**IMSS**		**SEDENA**		**SEDESOL**		**SEGOB**		**SEMAR**		**SMEXICO**		**SGUERRERO**		**SSPPC**	
Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)
4959223.7	100.9	5274897.3	85.1	5065977.2	100.8	5456865.7	85.0	5001441.2	98.0	4930519.7	101.5	6335253.2	70.2	4988061.9	95.3	8391163.4	38.0	4950889.7	101.0
5072037.3	98.9	5363847.3	83.6	5162403.1	98.2	5547128.3	83.3	5090052.8	96.7	5021068.8	99.3	6415935.9	68.0	5071822.8	94.0	8499175.9	37.6	5047608.5	99.3
5351920.1	98.2	5440774.5	83.3	5244972.5	97.0	5632636.6	82.0	5182417.4	95.0	5117270.8	97.2	6609008.3	66.3	5164070.6	92.0	8587313.6	36.0	5141530.3	97.2
5437675.3	92.3	5521299.3	81.0	5328685.7	93.1	5727027.5	79.8	5276501.4	93.3	5302260.7	94.3	6691419.7	65.7	5259961.5	90.5	8676024.1	35.2	5232525.0	95.6
5829168.3	84.0	5638304.0	79.8	5435506.0	91.9	5816533.4	78.3	5352923.6	91.7	5388727.0	92.0	6766796.5	64.8	5345662.0	89.1	8953073.3	33.6	5317418.0	94.0
6026208.1	83.3	5717758.3	78.1	5519946.0	91.1	5905163.2	77.0	5457992.2	90.2	5484131.1	91.2	6869557.6	64.6	5443151.9	86.3	9045302.1	33.3	5411529.9	92.6
6126176.2	80.9	5817413.9	77.2	5617275.8	89.1	5997779.0	75.9	5550400.1	88.9	5551308.7	90.0	6966095.9	62.5	5529679.9	85.3	9319021.6	31.7	5505970.7	91.0
6229834.8	78.7	5910084.7	76.0	5705095.9	88.0	6088689.1	75.1	5630378.6	86.8	5663625.0	87.9	7147234.4	59.7	5618751.0	84.7	9412225.6	31.3	5596167.4	89.4
6322772.8	78.3	5985715.4	75.5	5794576.7	86.0	6179505.4	73.7	5725613.0	85.7	5748222.9	86.5	7314003.7	59.3	5706424.9	83.1	9687024.3	30.8	5669179.4	87.6
6404582.0	77.3	6077270.3	74.1	5890364.8	84.4	6267327.7	72.8	5813785.5	84.2	5847706.6	85.3	7508278.5	58.2	5794846.4	81.8	9745395.3	30.7	5764087.1	87.2
6518651.0	74.0	6165605.0	72.5	5980405.7	83.3	6360806.1	71.3	5902397.1	83.0	5934291.8	84.9	7583435.7	58.0	5897340.3	80.0	9868080.0	29.7	5869992.7	85.1
6884811.7	72.9	6268251.6	71.4	6066828.7	82.4	6443890.1	70.9	5992317.0	82.0	6027136.7	83.3	7673460.6	56.6	5970512.4	79.2	10054456.1	29.3	5955340.9	83.5
6995877.9	71.9	6358571.5	70.4	6162044.9	81.5	6549123.1	69.1	6085506.8	81.4	6117706.2	82.4	7780134.7	55.7	6076495.7	78.3	10326270.1	28.7	6037601.3	83.3
7083941.1	70.1	6455679.6	69.1	6239482.4	80.6	6637366.8	68.4	6177192.3	79.8	6275995.1	80.0	7882434.1	54.6	6167828.8	78.1	10603524.8	27.8	6130702.1	82.0
7166886.7	69.0	6636818.0	66.3	6340260.5	79.5	6720318.0	66.7	6266940.3	79.1	6391371.4	78.8	8242668.5	53.3	6261602.3	76.4	10685178.5	26.7	6224198.8	80.0
7289062.4	68.0	6696371.3	66.3	6423856.9	77.5	6909883.9	65.8	6368612.7	78.4	6485574.4	78.2	8332709.4	52.3	6352306.2	76.3	11200552.6	26.1	6316707.3	79.8
7385439.6	67.7	6800870.2	65.0	6617832.2	75.6	6996362.0	64.6	6443051.8	77.0	6570467.4	76.4	8428792.6	49.1	6441665.9	73.7	11418789.4	24.5	6386058.0	78.9

7577959.7	66.9	7001127.7	63.2	6703225.9	74.4	7094594.7	63.6	6548175.6	76.0	6659431.3	76.2	8792320.4	46.5	6522309.5	72.7	11515281.1	24.4	6504876.1	77.8
7940485.0	64.1	7095294.7	62.5	6793236.9	74.3	7176999.7	62.5	6640983.6	75.3	6739324.7	74.8	8924874.0	46.1	6625807.0	71.3	11772204.2	23.8	6595415.5	76.2
8059373.1	61.4	7264906.7	62.0	6890685.6	72.2	7270925.8	61.9	6723267.4	74.7	6849173.4	73.0	9065354.3	44.9	6714299.7	70.6	11880732.8	23.3	6678147.2	75.6
8129290.4	59.5	7354931.5	60.0	7072283.5	71.4	7367964.9	61.3	6822975.1	72.8	6938404.6	72.7	9144539.1	44.1	6804150.5	70.0	12247622.5	22.8	6777404.9	75.0
8252097.4	58.7	7453162.1	59.5	7162601.3	70.7	7458122.5	60.2	6916115.0	72.2	7014636.7	71.8	9338073.2	43.3	6888206.5	69.4	12297121.6	22.4	6860977.8	73.3
8635612.5	56.2	7542571.7	58.7	7203437.7	69.4	7550180.3	58.7	6992184.8	70.2	7118806.7	70.0	9600813.3	42.4	6983777.2	68.0	12575697.7	21.9	6957248.9	71.4
8811703.6	55.3	7634300.5	57.9	7436719.5	67.4	7726976.1	58.3	7080462.3	69.3	7188655.9	69.5	9702927.0	41.8	7081271.4	67.3	12654862.4	21.6	7049320.6	70.5
9306305.7	52.8	7729590.1	57.7	7519849.1	66.7	7821753.2	57.9	7181574.5	68.8	7300180.7	68.2	9781894.4	41.1	7169281.7	66.0			7142391.5	70.0
9599576.4	52.2	7801810.6	56.9	7605021.0	65.0	7912130.4	56.4	7277303.1	67.9	7394500.4	66.7	9880182.3	40.9	7251274.8	65.8			7227575.2	69.4
		7903949.9	55.8	7771101.8	64.2	8085753.9	55.0	7347845.3	66.7	7572197.1	65.9	9976208.2	40.5	7350594.1	65.0			7318455.3	68.7
		7990418.4	55.1	7892479.1	62.9	8180707.1	54.6	7452751.7	66.3	7655047.6	65.6	10066073.0	40.1	7430432.4	64.8			7414920.3	67.4
		8086620.5	54.5	8070836.5	62.7	8275996.6	53.9	7552292.7	65.9	7748070.8	65.0	10153509.1	39.6	7517694.5	63.9			7461698.3	67.4
		8174953.1	53.8	8255537.8	62.2	8364669.9	53.3	7730090.0	64.4	7849702.0	63.8	10245638.0	39.0	7627362.7	63.1			7596573.3	65.8
		8259786.6	53.7	8335692.5	59.5	8549705.2	52.1	7811575.0	63.6	7929270.8	63.3	10325767.0	38.8	7718695.8	62.5			7774093.8	65.1
		8368253.6	52.9	8527053.4	58.8	8703875.5	51.4	7917041.5	62.7	8019750.9	62.8	10420100.7	38.5	7809294.7	62.2			7868989.7	64.0
		8531013.7	52.3	8603006.5	58.2	8812855.0	50.5	7994815.3	62.2	8119129.6	62.2	10510244.4	38.3	7892262.0	61.2			7959984.4	63.5
		8640050.4	51.4	8698824.5	57.3	8907129.2	50.0	8087900.1	61.0	8213685.0	60.9	10600783.9	38.0	7986746.1	60.4			8053478.9	62.8
		8730692.7	51.2	8790541.6	57.1	9083181.3	48.9	8188733.3	60.1	8391425.0	60.0	10702177.3	37.8	8080062.2	59.3			8130607.4	62.7
		8873112.7	49.6	8891493.8	56.7	9188089.8	48.3	8280905.6	59.8	8483892.3	59.3			8166354.6	58.7			8234839.0	60.9
		9003461.5	48.7	8979606.8	55.6	9276365.1	47.8	8365917.5	59.3	8570079.7	58.8			8254646.0	58.3			8325895.3	60.0
		9095192.5	48.6	9165893.2	54.9	9524779.6	47.6	8461838.4	58.2	8667869.0	58.0			8353963.1	57.1			8499960.0	59.4
		9180305.1	48.4	9254683.1	54.7	9628613.3	46.9	8544069.3	58.1	8759821.7	57.3			8441106.3	56.8			8597410.9	58.7
		9272200.5	48.0	9336621.1	53.8	9722608.5	46.3	8645243.1	57.1	8933387.9	56.4			8537644.7	56.6			8686482.0	57.8
		9368121.4	47.5	9426469.8	53.8	9815517.1	46.1	8821514.7	56.2	9025617.5	56.0			8626317.9	56.3			8769904.5	57.1
		9543187.6	47.0	9510951.0	53.3	9914159.6	45.7	8914377.8	55.8	9119731.6	55.6			8698152.3	55.0			8950471.0	56.4
		9641932.8	46.5					9007124.2	55.3	9214565.9	55.0			8804295.7	54.5			9054700.4	55.6
		9729414.5	46.0					9093089.8	54.7	9304533.5	54.7			8898572.1	53.6			9234368.3	54.8
								9183851.0	54.3	9395690.4	54.4			8970228.1	53.3			9320717.9	54.7

								9280494.4	53.9					9082813.8	52.9				
								9372842.8	53.3					9170764.6	52.8			9417301.8	54.2
								9460441.2	53.1					9261525.8	51.9				
														9356639.1	51.7				

Villahermosa

Finally, the independent incursion of governmental agencies for disaster management was tested on the flood in Villahermosa in 2007, yielding the outcome displayed on Table K.3.

Table K.3. Set of efficient points obtained from the application of the preparedness model to the thirteen agencies in Villahermosa

CENTRO		**DICONSA**		**DIF**		**IMSS**		**ISSET**		**PC**		**SMEX**	
Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)
36514210.3	107.7	36696028.0	101.8	36546344.8	103.3	36664074.6	104.9	36603194.7	105.3	36553300.4	107.3	67994044.4	59.9
36583104.8	104.6	36870184.7	100.9	36625993.5	102.0	36743248.7	103.3	36679358.5	104.3	36628550.0	102.3	68232014.2	59.3
36667663.5	102.4	36957392.6	100.5	36780414.6	101.2	36820607.3	102.2	36831735.8	101.8	36709824.8	101.2	68384861.6	59.1
36978528.1	102.2	37218687.3	100.1	36853465.5	100.9	36970882.4	100.8	36991408.0	101.8	36790928.3	100.6	68536359.0	58.6
37183668.9	101.5	37305780.1	99.6	37097492.1	100.4	37051996.5	100.7	37225193.8	101.0	36868699.7	100.6	68624753.1	58.6
37681989.7	101.3	37479899.9	99.1	37166768.1	100.1	37200006.7	100.6	37459890.4	100.0	37100642.0	99.9	68939036.0	58.1
38040993.0	100.8	37648071.1	98.8	37233011.1	100.0	37280074.6	100.3	37569973.2	99.7	37726029.1	99.7	69178776.8	57.2
38048714.3	100.4	37828308.5	98.4	37474103.4	99.4	37363759.3	100.1	37682229.2	99.2	37874421.1	98.8	69875759.9	56.7
38678653.3	100.0	37914965.1	97.7	37719285.1	98.4	37512554.5	99.3	37848349.0	98.9	37951151.8	98.3	70127203.9	56.6
38778519.0	99.2	37999967.6	97.4	38071667.8	98.0	37759688.5	98.8	37924639.3	98.9	38040415.6	98.0	70592230.1	56.1
39018808.2	96.9	38259169.5	96.8	38977463.9	96.7	37916290.5	98.6	38010767.8	98.5	38355844.5	97.4	70998767.0	55.8
39957705.4	94.6	38612192.2	96.6	39125165.3	96.6	38072116.6	98.3	38168556.0	98.0	38898518.9	97.1	71084850.8	55.6
		38699269.2	95.8	39286138.7	95.7	38778947.5	97.7	38243909.3	97.8	39130249.1	96.4	71408184.8	55.1
		39044742.5	94.6	39520487.3	95.5	39090258.3	96.8	38867042.8	96.6	39600698.6	95.3	71485289.2	55.0
		40260882.4	93.7	39602208.7	95.3	39168242.4	95.8	39332512.8	96.2	39764551.4	94.3		

		40350902.0	93.3	39759146.9	94.7	39483276.4	95.4	39570112.8	95.2	40388948.9	93.3		
		40869069.5	92.9	39994076.5	94.3	39555706.5	95.1	39805607.5	95.0				
				40384905.3	93.3	39715563.6	94.7	39890166.6	94.7				
						39953562.6	94.7	40032712.9	93.9				
						39953674.0	94.4	40283001.9	93.3				
						40188705.5	93.9	40388724.1	93.2				
						40419758.6	93.3						

STAB		**SEDENA**		**SEGOB**		**SEMAR**		**SCT**		**SSP**	
Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)	Cost	UFR (%)
40718326.4	98.4	47674422.8	77.4	36526602.7	103.9	37156627.6	103.2	36536223.0	103.3	40403462.8	81.2
40813365.3	94.4	47750448.7	73.0	36589992.7	102.5	37239271.4	101.3	36617293.4	102.4	40749476.0	79.6
40907472.0	91.2	48065598.0	69.9	36761427.4	102.2	37319045.1	100.2	36852725.8	100.9	40938690.3	79.6
41281177.0	90.5	48979677.5	69.2	36834161.5	101.6	37397306.1	99.0	36921454.4	100.9	41037783.7	79.2
41653105.4	90.5	48994762.3	67.9	36917679.8	101.0	37553603.9	98.0	37001672.5	100.3	42014148.1	78.7
41734521.7	89.1	49284337.6	67.6	36992425.9	100.7	37637526.8	97.9	37166566.9	100.1	42264811.4	77.1
41840999.6	88.9	49862156.1	67.5	37230733.5	100.0	37701769.7	97.1	37242149.1	100.0	42454437.3	76.6
41934753.5	88.2	50103298.3	66.7	37389373.1	99.5	38336626.4	96.1	37323185.4	99.6	42515783.1	76.2
42209886.5	88.1	50259926.7	64.9	37696477.4	98.9	38420901.8	96.0	37713097.3	99.4	42708489.3	76.0
43052050.8	86.1			38010474.9	98.6	38577389.9	95.8	37869468.9	99.2	42952244.4	75.6
43894121.0	84.4			38252099.3	98.4	38967773.6	94.8	37949506.1	98.1	43306331.4	75.4
44270699.7	83.4			38690604.4	97.9	39877297.5	94.2	39107942.7	97.2	43467327.0	74.8
				39339889.2	97.5			39358841.3	95.8		
				39419347.0	95.8			39436637.3	95.7		
				39737134.9	95.5			39749068.9	94.3		
				39815974.5	95.2			40376421.7	93.3		
				40106640.1	94.2						