Supply Chain Management for Medical and Psychological Assistance in Post-Disaster Calamities Situation - Case Flood

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Abstract—The humanitarian logistics supply chain can be described as a network of volunteer staff and that interact with a set of goods and services, this with the purpose of satisfying the demand of the population affected by a sudden flood. This article focuses on the formulation of a model's location to a point of distribution and multiple shelters whereas flood risk associated to the area, along with a model of routing of specialized personnel, allowing to relieve the psychological and medical calamities among other present in the population affected in a post-disaster situation; This formulation is made by applying operations research as a solution tool. The aim of this article is to provide a functional model to strategically design network facilities, in addition to coordinate the provision of services required by the population in the shortest possible time. The flood that the town of Santa Lucia, Colombia suffered in 2010 is taken as a case study.

Keywords—Humanitarian logistic, location of shelters and a distribution point, risk area, routing of staff.

I. Introduction

When discussing a flood there are two possible causes: the first is related to natural phenomena such as rain and the rain seasons, the second cause is man-made actions that induce to a large extent natural disasters [1]; These causes include deforestation, damage to watersheds and elimination of wetlands, which contribute to the intensity of floods, landslides and droughts. Additionally a flood may be the side effect of another disaster that occurred in the area. On the other hand, the cutting of mangroves on the coasts contributes to coral erosion, generating storms and hurricanes; the main effect that causes most of these disasters is "human development", which causes the reduction of the ozone, generating climate change along with other problems [2].

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Floods can be classified into two types: sudden floods and progressive flooding. These have specific characteristics that vary according to the area of occurrence, i.e. the effect of flooding is not the same in a rural area as it is in an urban area. This article will analyze sudden flooding in rural areas, which is caused by rains, storms and hurricanes, among other causes [3].

Sudden floods are characterized by the high level of water and the speed with which it attacks; it is estimated to be within minutes or hours that the area is completely flooded. These can be caused by the rupture of dams, dykes or torrential rains in flat areas, and such events are not possible to detect or predict. Because of this floods are credited with the highest rate of mortality among natural disasters [4]. A flood can drag rocks, knock down trees and destroy infrastructure, generating a large number of deaths and injuries of all kinds. Floods, without exception, generate damage to the population, infrastructure and the damage of a region, giving way to the spread of diseases and the complexity in which the disaster response must perform their operations [3].

To mitigate the impact of the disaster, some organizations such as the Red Cross have developed training programs aimed at the population and institutions impacted; parallel to this a series of protocols and guidelines for the management of such situations have been developed [5]. Despite these measures, floods are natural disaster that present the greatest number of lives lost and affected population [6].

There are two major phases identified in floods and other disasters: the pre-disaster stage and post-disaster stage. Each of these frames a series of operations; the pre-disaster stage focuses on operations preparation and plans of response. In this stage, operations refer to activities related to drills and lines against a flood. The post-disaster phase has two operations: mitigation and recovery. Mitigation operations refers to the design of the logistics network which will allow an optimum operation. Recovery refers to the revival of the population and the area [7].

This article is framed in the post-disaster phase and in the operation of mitigation of the negative impact of the flood. From a strategic point of view determining the optimum location of shelters and from a of operational point of view by defining the optimal distribution of qualified personnel from a distribution point until shelters, with the aim of having a minimum distance between the locations and at the same time ensuring reduced travel times. The article is divided into: II.

Literature review. III. Approach of the problem. IV. Case study. V. Result. VI. Discussion. VII. Conclusions.

II. Literature Review

The location of the points of distribution and multiple shelters, is the starting point for the design and management of the supply chain [8]. Location has a great impact on the operation of distribution of humanitarian aid, so the article's [9] defined a criteria to measure the performance of the location, these criteria are related to travel times, transportation costs and equity.

The process of facility locations and transport are operations that are closely related, since the facilities location affects routes and the effectiveness of the assistance required by the population. According to these considerations B. B. Balcik y B. M. Beamon [10], propose a model of temporary location, where the points are re-located according to the requirements of the area or to the requirements of the route, While [11], [12] propose a discrete location models including routing and distribution of food, medicines, water, etc. having as starting point the fixed points of the multiple shelters. The main objective is to improve performance in terms of response times, from the supply chain.

III. Approach of the Problem

This chapter presents two models, the first arises to solve the facility location problem and the second intends to solve the problem of the distribution of personnel. The model is constructed through the application of operations research.

A. Problem Description and Assumptions for Location Model

The proposed model seeks to solve the problem of the installation of a point of distribution and shelters in a neighboring area to the area affected by the flood, to determine potential geographic points considering the probability of risk of flooding in each selected area. The model aims to reduce the time of travel between the distribution point and shelters; thus seeks to ensure that the designed supply chain allows for the assistance of the population affected in minimum response times. The facilities location is based on the assumption that the flood-affected region lacks infrastructure to house and assist the affected population, so it is necessary to evacuate and install this population in safe areas with the purpose of providing the assistance required. In addition the proposed model considers that regions close to the flooded area have an associated risk of flooding.

According to the issues raised by [13] to formulation of the model, the region affected by the flood is divided into sub-zones, and from these sub-zones it was establish that many people must be evacuated and installed in shelters; this model is based on the assumptions that shelters have the same capacity in number of people and the certainty of demand, i.e. the points where the population needs to be evacuated is known with certainty. It is important to clarify that the proposed model is focused on location and not on the evacuation process; however the proposed localization model considers the number of families with some sort of calamity, requiring them to be evacuated and installed in a shelter located in a safe area. Therefore the article focuses on the installation of a point of distribution and multiple shelters.

In addition to the location of the shelters and the installation of a single point of distribution is defined on the basis of a post-disaster situation, which is characterized by damage to access roads, disruption in the information network and the provision of goods and services [14]. According to the experiences of humanitarian aid organizations, operations related to the management of a post-disaster situation are uncontrolled and uncoordinated due to lack of information [3], in addition multiple distribution points causes shelters to be supplied by mistake more than once, leading to inefficient use of limited resources. For these reasons a single point of distribution is considered to ensure the centralization of information, allowing a coordinated and efficient operation.

The facility location is the critical decision in managing the post-disaster of a flood, as that is the operation that defines the supply chain. The definition of points for facility locations are part of the strategy for post-disaster management, therefore the speed with which responding to calamities in a disaster depends on facility locations, as well as the success of supply chain operations. To consider these aspects, a mathematical model is proposed that seeks to reduce the time of travel between the distribution point and shelters.

In the commercial supply chain the main objective is the reduction of logistics costs that are considered fixed costs and variable costs associated with the facility location. In the proposed model considered constraints and goals related to suffering of the affected population and at the same time ensure compliance with human rights, these constraints and goals were not considered since management in post-disaster situation [15].

B. Location Model

For the formulation of the first model datasets and indices were determined, then the variables and parameters.

a) Notation

Sets and indices

- V Set of areas that are potentially unsafe $\{I \cup J\}$
- I Subset of V that describes potentially safe areas to install the distribution point.
- J Subset of V that describes potentially safe areas to install shelters.
- D Set of sub-zones in the flooded region.
- M Set of calamities in the affected population.

Model

$$\text{Mínimize } Z = \sum_{j\in J}\sum_{i\in I} E_{i,j} T_{i,j} RA_j RCD_i \quad (1)$$

$$\sum_{i\in I} a_i = 1 \quad (2)$$

$$\sum_{\forall i\in I} E_{i,j} = b_j, \quad \forall j \in J \quad (3)$$

$$\sum_{\forall j \in J} E_{i,j} = F\,a_i, \quad \forall i \in I \tag{4}$$

$$b_j(F) \geq \sum_{d \in D} \sum_{m \in M} Q_j^{d,m}, \quad \forall j \in J \tag{5}$$

$$b_j \leq \sum_{d \in D} \sum_{m \in M} Q_j^{d,m}, \quad \forall j \in J \tag{6}$$

$$\sum_{j \in J} b_j \geq \frac{\sum_{d \in D} \sum_{m \in M} O_{d,m} + \Delta}{K} \tag{7}$$

$$\sum_{j \in J} Q_j^{d,m} \geq O_{d,m}, \quad \forall d \in D,\, m \in M \tag{8}$$

$$\sum_{d \in D} \sum_{m \in M} Q_j^{d,m} \leq K, \quad \forall j \in J \tag{9}$$

$$a_i + b_j \leq 1, \quad \forall i \in I,\, j \in J,\, i = j \tag{10}$$

$$a_i \in \{0,1\}, \quad \forall i \in I \tag{11}$$

$$b_j \in \{0,1\}, \quad \forall j \in J \tag{12}$$

$$Q_j^{d,m} \geq 0, \quad \forall j \in J,\, d \in D,\, m \in M \tag{13}$$

The objective function of the model (1) is to minimize travel between a distribution point and shelters, considering the risk associated to locate any type of installation in the area *i* or *j*, the risk is a parameters that penalizes journey times. Restriction (2) ensures that the number of points of distribution open is only one. Restriction (3) ensures that shelters will be attended whenever they are opened, (4) restriction guarantees that shelters can only be attended by this open distribution point. Restrictions (5) and (6) ensuring that a shelter can cater to a zone only if it is opened. (7) Restriction ensures that the number of shelters open is able to accommodate all of the affected population. Restriction (8) ensures that the number of people in each shelter must be greater than or equal to the demand of each zone. (9) Restriction ensures that the number of people in each shelter must be less than or equal to the capacity of the shelter. The set *J* is a copy of the set *I* so (10) restriction guarantees that an area may not have more than one use, i.e., the area is used as a shelter or as a distribution point. Restrictions (11), (12) and (13) characterize the variables considered in the problem.

C. *Definition Set Zone*

To start it is necessary to reference human rights, which defines that all people should have a safe and worthy place like the shelter [1]; Therefore the potential areas to locate the flood-affected population must comply with some considerations, which are related to protection against weather, spread of diseases and health problems. The objective of these considerations is to mitigate the effect of flooding on the affected population.

Potential areas should be characterized by allowing the supply of goods and services, compliance with topographical conditions as the inclination of the land cannot be greater than 6% or less than 1%, and ensure that it has a system for the disposal of solid waste and waste water, in the same way these areas should be located away from stagnant water, wastewater and of all types of waste [1], in order to prevent the emergence and spread of diseases.

Shelters and the single distribution point are installed in potential areas, which must have the shortest possible distance between them, in order to ensure easy access and prompt assistance for the affected population. Usually schools, churches, sports fields, and educational institutions in the neighboring regions to the flood are considered for shelters and distribution points [16], so the whole V refers to these types of places located in potential areas that comply with the characteristics listed above, and in addition must have some kind of infrastructure that will allow the assistance to the population. In the proposed model the capacity of the shelters is homogeneous, and the capacity the distribution point is associated with the number of personnel available to tend to the affected population.

E. *Definition of Risk of a Zone*

The determination of potential safe zones for the installation of a shelter or a distribution point depends on the region affected by the flood; so it is necessary to assess the risk for each of these areas in order to relocate the population affected by the flood and qualified personnel [1].

In this case the risk associated with each zone is defined as the frequency of occurrence of a flood in this area; these values are an input parameter for the formulation of the model, which are taken as factors that could cause increase or decrease time depending on the risk of each zone. The risk is an external factor that is important to consider, because badly located shelters and the distribution point represent a high risk of facing a second flood, which means double the efforts to assist the affected population and the increase in vulnerability to diseases, psychological disorders and loss of human lives among other problems.

F. *Definition of Calamity*

Calamities are the kind of health problems that can attack the population as a result of the flood. In the case of sudden floods, there are different types of problems that require a type of specific health care. Injuries that occur in floods are mostly not lethal, however, diseases carried by the flood can be. These calamities cause the floods are the natural disaster that generates the greatest number of lives lost [3], [5].

Sudden floods often cause the fall and the movement of trees, rocks, rubble and bulky items, which are the main cause of physical injuries and drowning of persons. Water contaminated with industrial waste is the main medium for the spread of dengue, malaria, cholera, diarrhea, hepatitis A and E, gastrointestinal, and respiratory diseases among other vector-borne diseases [3]. Other types of calamities are associated with a psychological component, mainly caused by forced displacement, the loss of relatives, and physical and sexual abuse among others [5].

The proposed model considers three groups of calamities by severity which were grouped in the following way (see Table I):

1. Medical calamities.
2. Psychological calamities.
3. Minor calamities.

Table I Grouping of the problems in the calamities groups.

Health problem	Calamity		
	1	2	3
Psychological disorders by flooding (Loss of family).		X	
Psychological disorders by flooding (Economic losses).		X	
Psychological disorders by physical and / or sexual abuse.		X	
Fracture.	X		
Crushing of limbs.	X		
Minor injuries.	X		X
Acute diarrheal diseases.	X		
Respiratory infections.	X		
Vector-borne diseases (Malaria, dengue, cholera, etc.)	X		

Every calamity requires the attention of a specific kind of personnel, however, in a post-disaster situation a coordinated staffing process does not exist and therefore the allocation is d randomly, implying an increase in the suffering of the affected population.

G. Description of the Problem and Assumptions for a Model of Personal Routing

The timely provision of medical and psychological assistance is part of the requirements of the affected population, by which this routing model focuses on the provision of specialized personnel that can alleviate the suffering of the affected population. It is necessary to remember that in post-disaster situations resources are limited, especially the human resource, which is required for optimal coordination to relieve the suffering of the population.

The model is based on the assumption that all kinds of staff are able to handle any calamity, however, the percentage of relief and the time that it takes each staff depends the type of calamity. This is the reason that the prioritization of demand is necessary to minimize and present control over the calamities.

The model proposed considers four types of personnel in the management of the post-disaster situation: doctors, nurses, psychologists and personal first aid; for each type of staff defined a attention time and a relief level by calamity. For the responses to calamities brigades or mobile units are defined for the purpose of providing support in the work of the medical personnel, nurses, psychologists and rescuers, i.e. staff not opera alone, operations are developed together with well-trained medical staff and personal first aid.

The demand for shelters is given by the numbers of families that require attention. It is a value that is known with certainty, since the above location model serves to assess and report the actual status of the affected population. Working in this way ensures that information is concentrated in a single point and from the coordination of personnel is optimal. Humanitarian logistics comprises two levels of coordination: national and international as the Pan American Health Organization, International Federation of Red Cross and Red Crescent, etc., which unite their efforts to provide assistance to the affected population in a timely manner. This highlights the importance of segmenting the type of personnel according to their knowledge and not according to the Organization to which they belong.

H. Routing Model for Staff

For the formulation of the first model datasets and indices were determined, then the variables and parameters.

a) Notation

Sets and indices

- I,J Set of locations $\{W \cup E\}$.
- W Subset Distribution Point.
- E Subset of multiple shelters.
- L Set mobile units.
- M Set of calamities present in the affected population.

Decision variables

- $X_i^{j,l}$ Binary. 1. If the mobile unit l goes from the distribution point or shelter i to shelter or point of distribution j. 0. Otherwise.
- Y Days used in the operation.

Parameters

- $TV_{i,j}$ Travel time between distribution point or shelter i to shelter or point of distribution j.
- $D_{j,m}$ The number of families suffering from the calamity m in the shelter j.
- $TA_{l,m}$ Time that it takes the mobile unit l to relief the calamity type m.
- C_l Number of families that can attend the mobile unit l a day.
- $A_{l,m}$ Percentage of relief provided by the mobile unit l when it attends the calamity m.
- V Number of nodes to visit.
- α Weight in goal function of the time of travel between the distribution point and shelters
- γ Weight in goal function of the time spent in the care for the affected population.
- φ Conversion factor from minutes to days for operation time.

Model

$$\text{Mínimize } Z=\sum_{i\in V}\sum_{j\in V}\sum_{l\in L}\sum_{m\in M} X_i^{j,l}(\alpha TV_{i,j}+\gamma TA_{l,m}D_{j,m}) \quad (1)$$

$$\sum_{j\in J} X_i^{j,l}=1, \quad \forall l\in L, i\in W \quad (2)$$

$$\sum_{i\in J} X_i^{j,l}=1, \quad \forall l\in L, j\in W \quad (3)$$

$$\sum_{\forall i\in I} X_i^{j,l}=\sum_{\forall i\in I} X_j^{i,l}, \quad \forall j\in E, l\in L \quad (4)$$

$$\sum_{\forall i\in I}\sum_{\forall l\in L} X_i^{j,l}C_l A_{l,m}\geq D_{j,m}, \quad \forall j\in E, m\in M \quad (5)$$

$$\sum_{\forall i \in I} \sum_{\forall l \in L} X_i^{j,l} \geq 1, \quad \forall j \in E \tag{6}$$

$$\sum_{\forall j \in J} \sum_{\forall l \in L} X_i^{j,l} \geq 1, \quad \forall i \in E \tag{7}$$

$$Y = \sum_{i \in V} \sum_{j \in V} \sum_{l \in L} \sum_{m \in M} X_i^{j,l} \varphi(\alpha TV_{i,j} + \gamma TA_{l,m} D_{j,m}) \tag{8}$$

$$u_i - u_j + VX_i^{j,l} \leq V - 1, \quad \forall i \in E, j \in E, l \in L \tag{9}$$

$$X_i^{j,l} \in \{0,1\}, \quad \forall j \in J, i \in I, l \in L \tag{10}$$

$$Y \geq 0 \tag{11}$$

Equation (1) describes the objective function of the model, which consists of two parts: the first is related to the travel time between shelters and distribution point and the second refers to the attention time for the affected population; for each part a weight α and γ of importance respectively is defined. Restriction (2) ensures that the staff available at the point of distribution is sent to serve the population. Restriction (3) ensures that all mobile units that came out of the distribution point must return to the same. (4) Restriction is associated with the balance between shelters, i.e., ensures the continuity of the route of the mobile unit. Restriction (5) determines the capacity of each mobile unit and the respective percentage of relief with respect to the attended calamity. It also ensures compliance with the demand. Restrictions (6) and (7) allow each shelter to be attended to by a mobile unit. Equation (8) represents the minimum number of days required to attend to the affected population. Restriction (9) ensures the breaking of the sub-cycles of routes. The restrictions (10) and (11) describe the type of variables considered in the model, where it is a binary variable and it is a positive variable.

I. Definition of Staff

Although all the mobile units are able to serve all the calamities, the percentage of relief varies according to the kind of mobile unit. The mobile units considered in the model differ from the type of personnel, for the model 4 types of mobile units are considered: mobile unit of personal first aid, which are trained to address minor calamities; the medical mobile unit; mobile nurses and psychologists mobile unit, integrated by three people: a doctor, a nurse and a psychologist respectively and two support people.

The percentage of relief provided by each mobile unit was determined according to the Delphi method applied to physicians, nurses, psychologists and personal first aid. Relief capabilities vary due to the type of professional, defining the matrix that describes the variation depending on the type of calamity and staff that attends it; this is because each calamity requires a type of personal specific attention to ensure the maximum possible relief.

The challenge in the management of the post-disaster situation is to provide timely assistance in reduced response times, so the proposed model considered the prioritization of demand through the allocation of appropriate personnel, i.e., supply staff representing a higher percentage of relief to the population concerned according to the type of calamity; with $A_{l,m}$ intends it to prioritize demand, i.e., to assign more trained personnel to every calamity in order to increase the level of survival of the population. The following describes the matrix (see table II):

Table II *Relief for mobile unit capacity* $A_{l,m}$

Mobile Unit	Calamity		
	1	2	3
Doctor	90%	80%	80%
Nurse	80%	10%	80%
Psychologist	20%	50%	10%
Personal first aid	20%	30%	20%

IV. Case Study

The developing countries or with high levels of poverty are those who have a higher risk of disasters [1]. For this article the Flash flood which the town of suffered Santa Lucia in the Department of Atlantic Colombia in 2010 is considered as a case study, (See Figure I), which has the characteristics considered in the model. Flooding affected the region and 1737 families left homeless [17].

Fig. 1 Town of Santa Lucia. Source: Bank of the Republic of Colombia [17].

A. Definition of Areas

To determine the sub-zones of Santa Lucía, the town is divided into north, south, east and west, resulting in four sub-zones. Socio-political issues in the region establishing that the shelters and distribution point must be installed in the town of Sabanalarga, Ponedera, Palmar de Varela, Baranoa and Barranquilla [16], the Table III describes the number of potential areas per Towns.

Table III Potential areas for installing shelters and distribution point

Town	Number of shelters
Sabanalarga	10
Ponedera	10
Palmar de Varela	10
Baranoa	10
Barranquilla	11

B. Definition of Mobile Units

The mobile units of doctors, nurses and psychologists have a capacity for 50 people per day [1], i.e. 10 families per day. The model considers mobile units presented in Table IV.

Table IV Mobile units considered in the model

Mobile unit	Amount
Doctor	2
Nurse	2
Psychologist	4
Personal first aid	6

V. Result

The validation of the models was carried out in commercial GAMS software with a time limit of 0.13 seconds for both an Intel (R) Core TM i7-4500U CPU 1.8 GHz with 8 GB of RAM. The localization model considers a total of 51 possible sites for the location of the shelters and the distribution point, from which 39 for shelters and 1 to the point of distribution are determined (See table V). These shelters and the distribution point are located within the shortest possible time between them. According to the approach of the problem considered, shelters refer to schools and arenas of the neighboring regions. These have the capacity of accommodating 50 families, i.e. on average approximately 250 people. Appendix A shows the number of families with each kind of calamity that are installed in the shelters.

Table V Model output location

Town	Number of shelters	Distribution Point
Sabanalarga	10	0
Ponedera	10	0
Palmar de Varela	10	0
Baranoa	9	1
Barranquilla	0	0

The routing model for the staff determines the minimum time of operation, considering travel time and the time required to assist the affected population. The results of the model determined the assistance of the entire population, however, not all mobile units are assigned. Flood assistance requires a minimum of one medical mobile unit and 2 mobile units of personal first aid. Table VI presents the route of the mobile unit of lifeguard, which is part of the point Baranoa 1, followed by Baranoa 10, Baranoa 4, Ponedera 10 and Sabanalarga 4, in that respective order, and finally ending in Baranoa 10. Each of the routes of the mobile units determined by the routing model is shown in Appendix B.

Table VI Route of mobile Personal first aid unit

Mobile units of personal first aid	
From	**To**
Baranoa1	Baranoa10
Baranoa10	Baranoa4
Baranoa4	Ponedera10
Ponedera10	Sabanalarga4
Sabanalarga4	Baranoa1

VI. Discussion

According to the management of the flood in Santa Lucia report, the flood began November 30, 2010, and on December 3 of that same year the population was evacuated. The performance of the humanitarian work was qualified as regular since it was left to attend a large part of the population, the spread of diseases which gave became Vector-borne diseases and respiratory infections. Finally the families returned to their homes on April 3, 2011 [16]. The cause of this performance was the lack of information and the small number of specialized personnel, according to the standards proposed by [1] it is estimated that the flood was attended by four doctors, four nurses and four psychologists, in addition to the mobile units of personal first aid.

According to the above the actual management of health emergencies was regular, the reason why the proposed model aims to fill the gap of coordination of staff, taking the installation of a single point of distribution in order to unify and to analyze the information and installation of hostels as a strategic decision all while ensuring the shortest distance between them. The proposed model presents a 45.47 operation time where 90% of this time is spent on calamities relief and 10% is part of travel times, for the actual situation the estimated operating time was more than 120 days [3] for which there is no estimates for the time spent in the support of the population and the time spent on travel routes, so that the proposed model represents an approximate improvement of 60% at the time of operation.

VII. Conclusion

The article discusses the problem of the location of facilities and the routing of staff through two models characterized as allocation - location and the travel salesman capacity problem CTSP, respectively, whereas real variables of a State of emergency in the municipality of Santa Lucia, Colombia. In the case of the problem of location, given the socio-political issues in the area, the neighboring regions have a number of facilities available to accommodate the affected population, which have a risk of flooding, in the case of study proposed in the article there are 51 possible places, of which the model determines as optimal 39 shelters opening and a single point of distribution. The routing of the staff in humanitarian aid applied in the case of study warrants assistance to 8681 people, i.e., 1737 families on average, which require assistance according to the calamity that ails them. The routing model considers three types of calamities and four types of mobile units, which are allocated from a point of distribution to multiple shelters, ensuring the fastest response time and the highest percentage of relief for the affected population.

The models proposed in this article are novel since there are no investigations focused on the provision of medical and psychological assistance in post-disaster situations and that consider the location of a single point of distribution and multiple shelters from a strategic point of view. The solution provided by these models is optimal, which ensures the efficient use of human resources and reflects improvement in the response time to a flood and in the level of relief of the population with regard to the actual situation, as shown in the case study.

Floods affect the world more and more frequently, for which it is necessary to propose new research focused on the level of satisfaction of the population affected. First implement heuristics and metaheuristics, which allow the analysis of the problem with more data. On the other hand the study of evacuation models that consider the stochastic demand behavior, as well as models of rescue in the hours following a disaster. For months after a disaster, it is important to consider socio-economic models that allow the reactivation of the economy in the affected areas and population.

APPENDIX A

Town	Calamity		
	1	**2**	**3**
Sabanalarga	1	3	50
	0	2	48
	0	0	50
	50	0	0
	2	3	45
	0	0	35
	0	0	50
	0	0	50
	0	0	50
	0	0	50
Ponedera	0	0	46
	0	0	25
	0	0	46
	0	0	2
	0	0	50
	0	0	50
	0	0	50
	0	0	50
	0	0	50
	50	0	0
Palmar de Varela	0	0	50
	0	0	50
	0	0	50
	0	0	45
	0	0	45
	0	0	28
	0	0	39
	0	0	45
	0	0	45
	0	0	50
Baranoa	0	0	45
	0	0	50
	50	0	0
	0	0	49
	0	0	50
	0	0	50
	1	0	49
	0	0	50
	50	0	0

APPENDIX B

Medical Unit	
From	**To**
Baranoa1	Ponedera4
Ponedera4	Ponedera6
Ponedera6	Ponedera8
Ponedera8	Palmardevarela6
Palmardevarela6	Palmardevarela4
Palmardevarela4	Palmardevarela1
Palmardevarela1	Palmardevarela2
Palmardevarela2	Palmardevarela7
Palmardevarela7	Palmardevarela10
Palmardevarela10	Palmardevarela9
Palmardevarela9	Palmardevarela3
Palmardevarela3	Palmardevarela5
Palmardevarela5	Palmardevarela8
Palmardevarela8	Baranoa2
Baranoa2	Baranoa3
Baranoa3	Baranoa6
Baranoa6	Baranoa5
Baranoa5	Baranoa9
Baranoa9	Baranoa7
Baranoa7	Baranoa8
Baranoa8	Baranoa1

Mobile units of personal first aid	
From	**To**
Baranoa1	Sabanalarga6
Sabanalarga6	Sabanalarga3
Sabanalarga3	Sabanalarga1
Sabanalarga1	Sabanalarga8
Sabanalarga8	Sabanalarga7
Sabanalarga7	Sabanalarga5
Sabanalarga5	Sabanalarga2
Sabanalarga2	Ponedera2
Ponedera2	Ponedera3
Ponedera3	Ponedera9
Ponedera9	Ponedera1
Ponedera1	Ponedera7
Ponedera7	Ponedera5
Ponedera5	Sabanalarga10
Sabanalarga10	Sabanalarga9
Sabanalarga9	Baranoa1

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