Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 162 (2014) 139 – 147
Procedia Social and Behavioral Sciences

XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística (PANAM 2014)

Reference Structure Model for Degree Alert Classification During Seasonal Hydrological Events for Humanitarian Assistence in the Brazilian Amazon

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Abstract

Recent events in the rivers of the Amazon region show the distinct need for concern in this region and the vulnerability of the Amazonian people in regards to these events. Organizations for humanitarian aid developed procedures in the Amazon region. But to what extent are these actions effective if little is done prior to disasters? This work seeks to develop a frame of reference for classifying alertness in cities likely to suffer from flooding and ebbing of the hydrographic network in the Amazon Basin. The objective is to serve warning to the riverside communities in the state of Amazonas, establish future provisions of supplies and to form a solid database of information concerning the needs and impacts of these events, hence creating a historical record.

Peer-review under responsibility of PANAM 2014.

Keywords: humanitarian logistics, reference structure model, location problem, vulnerability, natural phenomenon

1. Introduction

There has been a worldwide increase in the development of research on the subject of humanitarian logistics due to growth in the number of disasters, whether caused by nature or by man. Several studies focused on humanitarian logistics have been in the academic spotlight, highlighting those developed by researchers such as Thomas (2004);

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Peer-review under responsibility of PANAM 2014.
doi:10.1016/j.sbspro.2014.12.194

Beamon and Kotleba (2006); Van Wassenhove *et al.* (2008); Balcik *et al.* (2008); Tomasini and Van Wassenhove (2009); Kovacs and Speans (2007); Balcik *et al.* (2010); McLachlin and Larson (2011).

Recent events in the rivers in the Amazon region, including the record flood in 2009, followed in 2010 by the severest drought registered in the area since measurements have been taking place, show the distinct need for concern in this region and the vulnerability of the Amazonian population in regards to these events. In 2010, a formidable drought affected fishing activity and out of the 62 counties in the state, 61 (99%) became isolated (land locked). Because of these events, inland and rural communities were forced to travel long distances to obtain access to the rivers' channels (Neves, 2005). Organizations for humanitarian aid developed procedures in the Amazon region. But to what extent are these actions effective if little is done prior to disasters? Being seasonal, they have a high level of predictability, but the most important regional modal has suffered insubstantial considerations. Water transport in the Amazon basin is essential to the regional economy and its population (Araujo, 2006). This has a considerable importance on the internal and external circulation throughout the Amazon basin, exhibiting itself as the most significant means of circulation for goods, products, supplies and services to the region, in addition to being the only routine mode of transportation for certain areas.

With this study, we look forward to developing a frame of reference for classifying alertness in cities likely to suffer from flooding and ebbing of the hydrographic network in the Amazon Basin. The objective is to serve warning to the riverside community of the state of Amazonas, establish future provision of supplies and to configure a solid database of information concerning the needs and impacts of these events, hence creating a historical record. According to Kovacs and Spens (2007), preparation is paramount in cities with an intense history of natural disasters. This structure is based on a degree of variables including the regional population, existing infrastructure, periodic measurements of water levels, and analysis of historical events, among others. In contrast to the situation and emphasis of the current model (which focuses on imminent danger and post-disaster procedures), this study aims to classify the degree of impact, the assignment of personnel and authorities to regions in need and develop an enhanced method of distribution and inventory of supplies. The use of tools that update event information potentially increases the assessment capacity of what is needed (and tendencies) to serve communities and enable timely and appropriate decision-making with the conception of strategic plans and the proper execution of these plans.

2. Humanitarian Logistics

As a response to catastrophes, Humanitarian Logistics incorporates logical procedures, which consider a variety of operations in different moments as a response to various emergency situations. As the main objective, all of these operations seek to aid in the survival of people (KOVACS and SPENS, 2007). Time is a distinguishing factor in regards to disasters and the lack of timely aid can increase individual suffering. Humanitarian help is a continuous process of mitigation and in cases of seasonal disaster, it is possible to implement pre-positioned planning of goods and input, as well as the evacuation of the affected population by using information composed from prior disasters (APTE, 2009). Charles and Laura (2011) view the humanitarian operation cycle to consist of four phases: preparation, immediate response, support and removal. These can be seen in Figure 1.

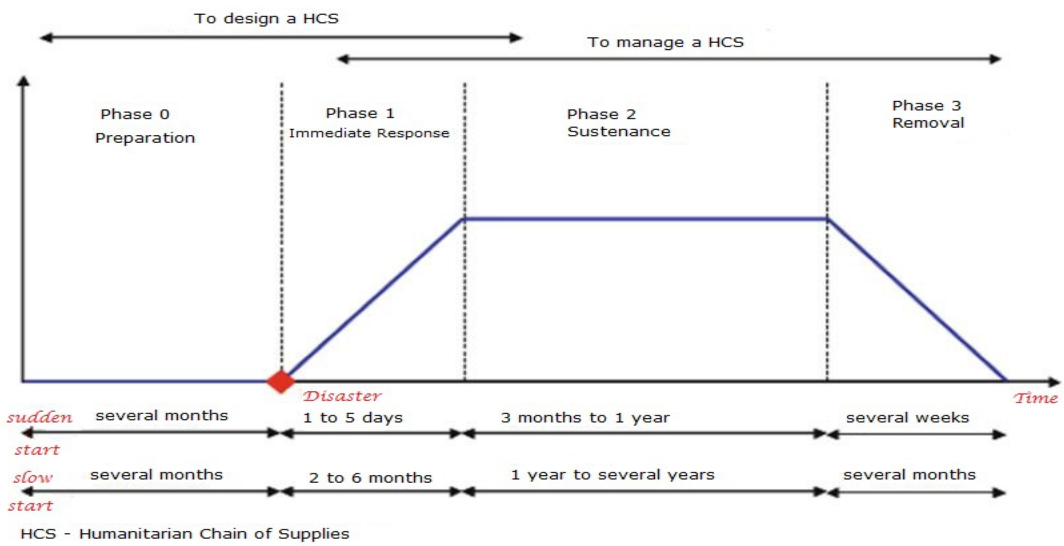

Fig. 1. Humanitarian Operation Life Cycle

Source: adapted from Charles and Laura (2011)

Preparation can play a vital role during catastrophes. Disasters with slow beginnings can provide help to humanitarian organizations to plan and prepare for rescue operations (APTE, 2009). On the other hand, sudden catastrophes can cause broad difficulties to organizational responses, since they are not given sufficient time to execute successful preparation for a specific event. The preparation phase addresses a strategy that permits the implementation of a successful operational response and activates the response mechanisms towards factors that society cannot attenuate. Thus, the work done between disasters can define procedures, mechanisms and dependable material to respond to dynamic areas of disaster and supports a rapid, adaptable and aligned response (TOMASSINI and VAN WASSENHOVE, 2009).

Depending on the type of disaster and those involved, the operational characteristics of the relief chain are different, or variable, according to the specific situation. The pre-disaster operations include the purchase and pre-positioning of supplies, while the main objective of post-disaster procedures are collection and transport (BALCIK *et al.* 2010). A rescue chain, for those involved, demands a series of procedures, facilities and activities that direct, coordinate and distribute necessary data to the affected communities, which may vary according to geographic location, incidence and the type of event that has occurred.

In a rescue chain structure, initially all supplies are sent by local/global donators and suppliers to a distribution center. This distribution center is generally located in major centers where the supplies are separated and transferred to intermediate stockpiles/distribution points. From there, they are sent to local distribution points and are given to the beneficiaries. It is important to note that the flow of supplies at the distribution center can occur before or after the disaster. Figure 2 represents the rescue chain structure of the pre and post disaster supply flow.

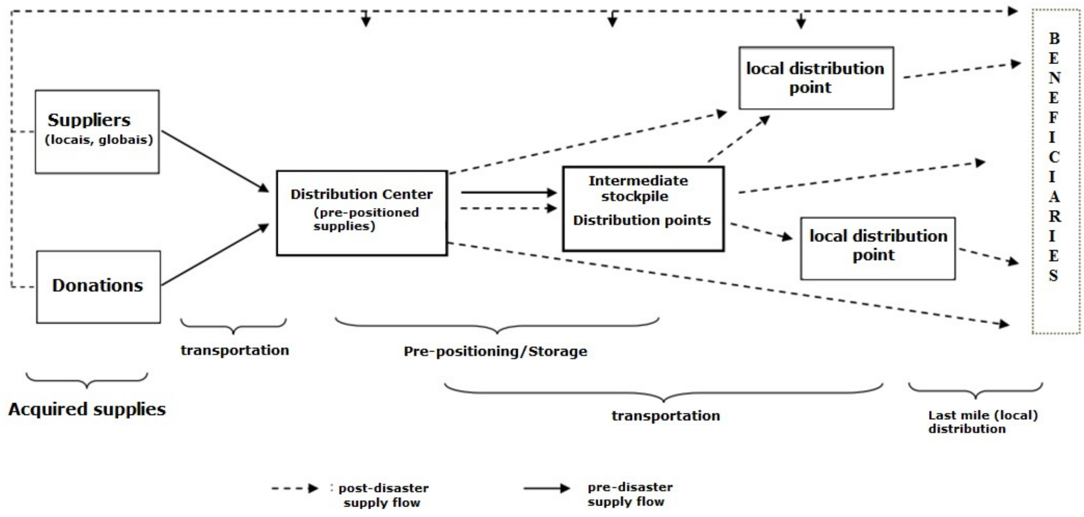

Fig. 2. Rescue Chain Structure

Source: adapted from Balcik *et al.* (2010).

The importance of this study is justified by the innate perception of the inhabitants of the small riverside communities throughout the state of Amazonas. Their history has been impacted by the water cycle that governs life and defines shorter or greater periods for the availability of food, means of transportation and the availability of goods and services. It is imperative to carry out methods to minimize the suffering of such a considerable population.

3. Reference Structure Model

This reference structure model for degree alert classification for seasonal hydrological events takes into consideration the knowledge of a specific natural phenomenon and the decided upon support mechanisms involved through an ontology capable of inference which can be modified dynamically with updates (knowledge) in regards to the seasonal situation of a given location.

The state of Amazonas is composed of 62 counties and is surrounded by the Amazon Basin and its affluent rivers. In this model we will consider the counties around the southern channel of the Madeira River, which is one of the most affected areas in terms of hydrological events in Brazil (IBGE, 2012). Those counties are: Humaitá, Manicoré, Borba, Novo Aripuanã and Nova Olinda do Norte. Those counties can be seen in Figure 3.

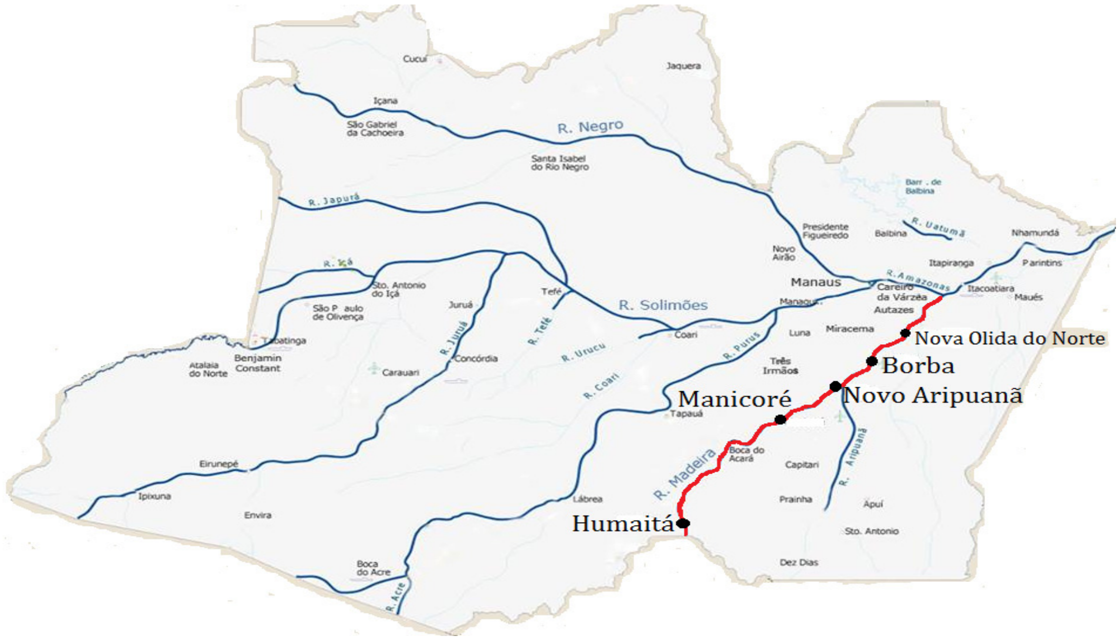

Fig. 3. Southern Madeira River Channel Counties

We attempted to make a historical analysis of drought and floods events in these counties. Considered greater weight in the last 3 years of analysis, since these appear to have greater correlation than the longer elaspsed time events. Defined diferences between three types of calaminous events: Droughts, Sudden Flooding and Gradual Flooding. The reason is that these events impact differently regional water transport, and, therefore, are made up of different barries for distinct events. Generally, the reference structure did not take into account the available infrastructure neither the population of the region (although these constitute risk factors in the location model applied), limited only to the volume history of the rivers in the analyzed places.

This study considered three types of events and two types of scenarios: Drought (the most serious, therefore usually impossible for long periods of time the supply arrival), Sudden Flooding (when rivers levels rise to alarming levels within 72h) and Gradual Flooding (river flooding happens after 72h of the beginning of the event); and about the scenarios: Scenario 1 – Old Events (happened four years ago or more) and Scenario 2 – Recent Events (happened in the last 4 years). For each event/scenario the following scores were given: Droughts score 2 points for events in Scenario 1 (older events) and 2,5 points for events happened in Scenario 2 (recent events); Sudden Floodings score 1,5 point for Scenario 1 events and 1,75 for Scenario 2; and Gradual Floodings score 1 point for events happened in Scenario 1 and 1,25 for Scenario 2. The ratio for the highest score in more recent events comes from the historiography of cyclical floods and droughts that plague that region, where past events have impacted the storage capabilities and the navigability in the following years, where the normalization only occurred in periods of tranquility. The greater weight given to droughts and sudden floods is given by the greater impact on existing structures and the isolation of these regions for navigation for longer periods of time, generating greater urgency in supplying pre-calamity. Chart 1 summarizes the scoring for each event adopted in this model:

Chart 1. Scoring model

Event	Past (4 years ago or older)	Recent (happened in the last 4 years)
Drought	2 points per event	2,5 points per event
Sudden Flooding	1,5 point per event	1,75 point per event
Gradual Flooding	1 point per event	1,25 point per event

Within the reference structure for determining the degree of risk of the state of Amazonas counties, historical analysis (1991 - 2011) of the events in these counties pertaining to southern Madeira River channel presented the following calamitous events: in Borba there were 3 significant droughts (2005, 2009 and 2010), 1 sudden flooding (in 1993) and 3 gradual floodings (2006, 2009 and 2010); Manicoré had 3 droughts (2005, 2007 and 2010), 1 sudden flooding (year 1993) and 3 gradual floodings (2006, 2008 and 2009);; Nova Olinda do Norte had 2 extensive droughts (2005 and 2010); 1 sudden flood (1993) and 2 gradual flooding events (2009 and 2010); Novo Aripuanã had 2 droughts (2006 and 2010); 2 sudden floods (1993 and 1994) and 2 gradual floodings (2006 and 2009); and Humaitá had 1 drought in 2005, 1 sudden flooding in 1993 and 2 gradual floodings in 2006 and 2009 (CPRM, 2012). Chart 2 presents the number of danger events to waterway transportation for the 1991-2011 period.

Chart 2. Number of danger events to waterway transportation in 5 Amazonas' counties (1991-2011)

	Droughts	Sudden Flooding	Gradual Flooding	Total Score
Borba	3	1	3	12
Manicoré	3	1	3	12
Nova Olinda do Norte	2	1	2	9,75
Novo Aripuanã	2	2	2	8,5
Humaitá	1	1	2	5,75

Source: CPRM (2012)

In order to classify the risk and help managing the goods in situations where it is needed, this model separates counties and assign weights on their population based in their scores after a historical analysis. For that, we have determined that Class A (scores higher than 11) counties are given a 30% weight; Class B (for counties scoring between 6 to 11), 20% weight; Class C (score ranging from 2 to 6), 10% weight; and for counties scoring less than 2 points, classified as Class D counties, a null (0%) weight.

4. Application

A mathematical model was developed to better define a system to locate Supply and Humanitarian Training Centers (SHTCs) that make full use of the waterway that encompasses the breadth of the system for this modal and test the reference structure model. In this manner, we attempt to stimulate and better estimate future needs and tendencies, thus applying the tool and increase support towards the stages of preparation and readiness on the verge of natural seasonal phenomena such as flooding and ebbing, in addition to the scaling of capacity and needs of the responsible authorities in the relief chains incorporated in the Amazon region. This location model was applied to the southern channel of the Rio Madeira that consists of 5 (five) counties: Humaitá (1), Manicoré (2), Novo Aripuanã (3), Borba (4) and Nova Olinda do Norte (5). Its modeling was carried out using the TSP (Traveling Salesman Problem) and cover sets to minimize the costs associated with distance and elapsed time. Its objective function is to analyze the cost of travel and transportation using IHABs (Itinerant Humanitarian Assistance Boat) relating to Itinerant Aid and Humanitarian Support Centers (IAHSCs) and the total cost for opening ensuing IAHSCs. The model is exhibited below:

4.1 *Problem Modeling and Solution Methodology*

For both, the aim is to administer to the greatest number of people affected by periods of calamity at the southern channel of the Rio Madeira in the fastest manner possible. Since the region for this channel encompasses 5 counties (Humaitá, Manicoré, Novo Aripuanã, Borba, Nova Olinda do Norte), when $N = \{1, 2, 3, 4, 5\}$, where each $i\ E\ N$ represents a county. The mathematical structure for the problem is conceived as follows:

$$Minimize \quad \sum_{j=1}^{n}\sum_{i=1}^{n} c_{ij}x_{ij} + \sum_{i=1}^{n} \lambda_i\,\theta_i \tag{1}$$

Subject to

$$\sum_{j=1}^{n} x_{ij} \leq \theta_i \qquad \forall i \in N \tag{2}$$

$$\sum_{i=1}^{n} x_{ij} \leq \theta_i \qquad \forall j \in N \tag{3}$$

$$\sum_{i,j \in S} x_{ij} \leq |S| - 1 \quad \forall S \subset N \tag{4}$$

$$\sum_{i=1}^{n} a_{ij}\,\theta_i \geq 1 \quad \forall j \in N \tag{5}$$

Where P_i is the rural population of the county and i, a_{ij} = 1 if location j is covered by location i by an Itinerant Humanitarian Assistance Boat (IHAB) or a_{ij} = 0 otherwise; θ_i = are decision variables, where θ_i= 1 if a SHTC is opened at location i or θ_i = 0 otherwise. The cost λ_i to locate a SHTC at local i was defined in the role of the rural population where the larger the population, the greater the risk of people affected, or rather:

$$\lambda_i = {}^{1}/_{((1 + W_i) \times P_i)} \quad (6)$$

Where W_i is the Reference Structure Model's respective weight for the location (based on its Class). Attaining the matrix $[a_{ij}]$ exhibits travel time between counties and the type of vessel used, 12 hours in the case of IHAB. These times represent round trip travel to and from the counties, since river currents and travel time vary. Therefore, the coverage matrix will be formed $[a_{ij}]$ if county j is covered by county i, given a critical service distance of 12 hours and $[a_{ij}]$ = 0 otherwise.

5. Results And Discussion

As seen above, the risk classification lies on a score that considers past emergencial events to assign weights to the respective counties. Therefore, the risk classification of the counties according to the proposed reference structure model is defined as follows: Class A: Borba, Manicoré and Novo Aripuanã (30% population weight); Class B: Nova Olinda do Norte (20% population weight); Class C: Humaitá (10% population weight); and no counties were given Class D classification.

Original model ($W_1, W_2, W_3, W_4, W_5 = 0$): The result indicated that 3 SHTCs would open corresponding to Humaitá, Manicoré and Borba counties. However, a SHTC would not be necessary in Humaitá County since it is already a Distribution Center. Consequently, the covered counties would be 3 (Novo Aripuanã) and 5 (Nova Olinda do Norte). Utilizing the all or nothing location, county 4 (Borba) covered counties 3 (Novo Aripuanã) and 5 (Nova Olinda do Norte) respectively using IHABs. Since the IAHSC mandatorily moves from 1 (Humaitá) to 4 (Borba), and from 4 (Borba) the IAHSC moves to 2 (Manicoré). From location 2, the IAHSC moves to location 1 (Humaitá).

Results applying the reference structure model weights ($W_2 W_3\ W_4 = 30\%$; $W_5 = 20\%$; $W_1 = 10\%$): The result indicated that again 3 SHTCs would open corresponding to Humaitá, Manicoré and Nova Aripuanã counties. Again, a SHTC would not be necessary in Humaitá County as it is a Distribution Center. So the new covered counties would be 2 (Manicoré) and 3 (Nova Aripuanã). Utilizing the all or nothing location, county 4 (Borba) covered counties 2 and 3 respectively using IHABs. Since the IAHSC mandatorily moves from 1 (Humaitá) to 4 (Borba), and from 4 the IAHSC moves to 3 (Nova Aripuanã), and then moves back again to location 1 (Humaitá).

The results indicate that Nova Olinda do Norte would be the substitute to Borba because it is more susceptible to the region's historical droughts and floods as the weight applied indicates that the population of this county is severed by these events.

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