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A Qualitative Analysis of Inventory Management Strategies in Humanitarian Logistics Operations

Elma Irais Mora-Ochomogo, Jaime Mora-Vargas, Marco Serrato
Tecnológico de Monterrey
A01104761@itesm.mx, jmora@itesm.mx, mserrato@itesm.mx

Abstract. This paper presents an analysis of the special characteristics of Inventory Management for humanitarian operations. Each year, many natural and man-made disasters occur, affecting thousands of people around the globe. During these catastrophes, both, government and humanitarian organizations, face great logistics challenges in which the main objective is to satisfy the needs of people touched by such disaster, to mitigate their suffering. To achieve such objective, an adequate Inventory Management Strategy in these logistics operations plays a crucial role at each echelon of the Supply Chain. This paper also aims to identify the state-of-the-art of Inventory Management Strategies and models used for humanitarian logistics operations as well as commercial models with the special features related to it. It includes its categorization according to crucial criteria and the identification of trends, gaps and challenges in this field, in order to provide valuable insights for future research in this domain.

Keywords: Inventory management; Humanitarian Logistics; disaster relief

1 Introduction

It took only 20 seconds in the life of people in Nepal to be shattered by the 7.8 earthquake that struck on April 25th. In this catastrophe, there were over 7 thousand casualties and almost half a million houses were either destroyed or damaged, leaving around 8.1 millions of people to be assisted with at least the basic needs [1]. Just like this crisis, millions of people are affected each year by either natural or man-made disasters, leaving the local and international humanitarian institutions with the greatest challenge of supporting an affected population to recover from the emergency and help them return to their normal lives.

The term Humanitarian Logistics (HL) encompasses a wide range of operations including the distribution of medical supplies for routine disease prevention, food supplies to fight hunger, and critical supplies in the aftermath of a disaster [2]. All the logistics efforts represent 80% of the total humanitarian efforts in any of the Humanitarian operations [3] this implies a great responsibility in the humanitarian entities, but also in the academic sector to make efforts to improve the logistic performance in the humanitarian endeavours.

An essential part of the success in any supply chain is the adequate management of the inventories in every echelon of it. In the case of HL aims the adequate inventory control and maintenance from the collecting points to the distribution points can make a difference between life and death. Classic inventory strategies hardly adjust to the conditions found in a crisis or tragedy, these challenges humanitarian logisticians to develop more adequate strategies and models to manage the inventories of supplies and help in any emergency.

The aim of this paper is to present some of the key differences between commercial and humanitarian inventories. This with the purpose of stating why the classic inventory models are not always the most appropriate way to manage inventories in a humanitarian scenario. In addition, a literature review and categorization from the different publications that address this subject will be carried out.

The reminder of this paper is organized as follows. Section 2 describes the particular features in inventory management that are set in a disaster situation and the challenges they imply. Section 3 defines the research methodology used to develop the literature review presented in this paper. Section 4 presents the literature review focused on inventory management previous or after a disaster strikes. Finally, section 5 presents the trends, future research directions and concluding remarks.

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2 Inventory Management In Humanitarian Logistics

Within the literature, research has been done concerning the differences between the commercial logistics and humanitarian logistics [2] [3] [4]. Including the challenges the latter has been dealing with: the uncertainty of the demand, the disruption of the roads and the communication channels and the challenge coordinating the many stakeholders involved in the process among others.

Focusing on the inventory management the next subsection will describe some of the special situations of the Inventory Management during the disaster relief. In addition, why these special conditions make it difficult to apply the classic inventory strategies, which have been widely developed, to humanitarian inventories.

2.1 Time is Crucial

The entire humanitarian supply chain is moved by the desire of supporting people in need and in most cases, help is needed as soon as possible. This fact leads the expenses to take a second place in the goals of the supply chain and specifically in the inventory management; it means that humanitarian logisticians will try to pre-position and have ready certain amount of supplies independently of the holding cost this represents.

Most classic inventory models seek to minimize the inventory cost with strategies like Just In Time to avoid the "unnecessary" storage. In the humanitarian's case, the inventories' goal is not quite defined; it could depend on the organization's motto, if they have recurrent activities or if they attend sporadic situations like sudden catastrophes, among other circumstances. In the case of the International Federation of the Red Cross (IFRC) the goal is to have pre-positioned enough to reach 5,000 families within the first 24-48 hours and additional 15,000 families within 14 days.

2.2 Non Repetitive Inventories

Many of the classic inventory models and strategies tend to establish a static horizon of time and given the conditions when a cycle is created making the inventory management a more standardized and efficient process. In a disaster relief situation, inventories cannot be designed like a repetitive model [5]. This is caused due to the nature of the sudden onset disasters, the time, place, impact and needs are unknown before and even short time after the disaster strikes; the uncertainty in the disaster setting makes it problematic to make decisions such as what and when to send or purchase.

After the disaster strikes, the inventory management decisions have to be made with the information available in that moment that was probably not the same information as the period before and will not be the same as the period after; this makes a very difficult job to plan ahead and try to standardize the process in a repetitive way.

2.3 No Backlogging Allowed

Another meaningful condition in humanitarian inventory models is that the concept of backlogging is not an option [5]. In classic inventories -depending on the organization or industry- backorders are not an uncommon situation generating backlogs in the production that can be delivered when they may be ready.

In the case of man-made or natural disasters, human lives are at stake and supplies arriving late or incomplete could have a fatal result in the affected population; therefore, if the supplies are not available at the moment they are required, they can be considered as "lost sales" in the commercial world and they will not accumulate for later delivery.

2.4 Donations Uncertainty

The supply process in these situations in most Non-Governmental Organizations (NGOs) is based on donations as the situations that come after a catastrophe might compromise the commercial supply chains depriving them from doing their usual role. As donations come, either in the form of money or supplies, and considering that donors are not obliged to fund any given disaster situation [6] the available supply for a certain disaster in a particular time can be very variable depending on the multiple-suppliers and donors.

Donors look for an organization with great accountability and less inefficiencies [7], this drives the organizations to have more transparency in their expenses and justify them to their sponsors with the intention to gain reliability and attract more donations.

Another important variable in the donations for each disaster is the visibility the media gives each event. This has a critical impact in the donations each organization receives and thus the supply each collecting point receives.

2.5 Scarcity and Surplus of Resources

Matching demand to supply is a particular problem in pre-and post-disaster relief activities [8]. Scarcity of vital resources in the affected area or region is not a rare situation during times of crisis; the local or even national inventories may have been affected or destroyed in the event and there is not enough supply to satisfy the demand at the time of need.

On the other hand, another issue that can be found in the disaster relief situations is what donors can or want to provide for the affected people not always match with the needs at the site. This means that unsolicited donations at certain time may arrive to collecting points and in the warehouses this causes the consumption of limited resources and hinders the flow of the necessary resources to the affected people. In these cases, some organizations choose only to accept the required items despite there might be disagreements with donors.

2.6 Prioritization of goods needed

Just after a crisis, the population's needs could be so diverse that decide which supplies could be lifesaving and need to be sent as soon as possible, and which ones can wait to be sent days after certainly represent a big challenge for the humanitarian logisticians.

With all the different needs in the affected zone, the variety of supplies that arrive to the warehouses and the limited transport capacity, access and storage space there is almost always a need to prioritize what is moved first.

2.7 Human Resources Variability and Availability

As the funds and the necessities of each operation can be very different, the sustainability of Human Resources will not always be the same and might vary in each operation as well. The funding might not only vary the quantity of people working in the operation, but also the preparation of each of them. This situation leads many times to people along the supply chain doing many different activities and multitasking.

The implication that such situation presents for effective and efficient Inventory Management is that all people involved with the warehouse management will not always be the amount of people required and they might not be trained and prepared to do all the necessary or specific activities needed in the warehouse.

2.8 Supplier Development

In the case of a high magnitude disaster or catastrophe the major source of supplies will arrive from abroad through the government, NGOs or other international organizations, increasing the delivery time. This is because depending on the specific conditions of the disaster the local inventories may be destroyed; in this case the local supplier's role becomes minimal [2]. If the local supplies are available and in good conditions will be used first and then supplemented from abroad supplies if needed.

To be prepared for these situations the organizations must find previously potential suppliers and sources to obtain the needed items [9]. This situation is not found in the private companies because of the effort that entails with no tangible or immediate benefit. The suppliers for humanitarian tasks should meet specific characteristics to provide the efficient service needed, for example, be the closest to the disaster area as possible, have the capacity required at the time is needed among others.

2.9 Expiration and Obsolescence

Pre-positioning inventory to be prepared in case a disaster strikes are used by most of the different organizations involved, however, from the moment that they will be used is highly uncertain, there might be a long period with a very low turnover, this causes that some items might eventually expire or in the case of technology, they might become obsolete.

Many inventories, such as food and medicines, have expiry dates that must be honoured [9]. As the goods stored will not be used until a disaster hits, and this could be indefinite, the managers should be particularly aware of the expiration dates of the supplies that are aimed to be used as provisions in an emergency and replace the non-suitable inventory opportunely.

In the case of the equipment stored to use in case of an emergency, after some time and with new technologies being developed, may become obsolete; therefore, it is important to verify in regular basis that the equipment that is intended to be used is appropriate and useful in the particular humanitarian conditions.

2.10 Warehouse Location

While in the commercial sector the warehouse location is much of a strategic and permanent decision, this is why it takes time and a more profound cost-benefit analysis to meet the optimal location and conditions.

In the humanitarian world in case of an emergency, as stated before, short time response is imperative and the conditions are very variable, therefore the warehouse location in-site in a first instance becomes more a matter of availability than strategy.

The options for selecting the warehouse type and location in-site become restricted. The humanitarian logisticians will source the best location available in the area of operation looking at access routes, equipment available and from it is expected the goods to arrive, including air, sea and land. As the general conditions will evolve through time warehouses must be enough flexible to be set in houses, offices or even in tents, almost anywhere can become a temporary warehouse. These kind of conditions makes the stock management different at each event, and even in each location.

2.11 Political and Cultural Matters

During humanitarian situations, the principal administrator of the operations handled is the national and/or local government, this implies that political and ideological matters will inevitably take part of the situation. The corresponding government will have a say in the organizations that will enter the affected area, as well as the suppliers and supplies; this situation is important to consider in the humanitarian affairs because it can alter significantly the plans of any institution, while the private companies do not have to deal with this type of issues.

In the case of the type of supplies that arrive to the affected place some cultural or even religious beliefs may restrict the use and limit the relief efforts, then, in order to have an accurate and effective performance in the humanitarian endeavor is critical to consider each case independently and make particular decisions.

3 Research Methodology

In order to make this research as complete as possible and given the limited literature focused on inventory management in disaster relief, a systematic review methodology was used. This section presents the systematic methodology conducted to provide a structured and reproducible way [10] [11].

3.1 Identification of Research

In this phase the aim, needs and goals of systematic review are established. In this research the goal is to find as many primary studies relating to inventory management models and strategies developed to attend the humanitarian situations or are developed to work under some special circumstances presented in the previous section.

3.2 Material Collection

To do the research 5 databases were selected as search engines; EBSCO Academic Search Premier, ProQuest Science Journals, ProQuest ABI/INFORM, Emerald Insight and Web of Science. The keywords “humanitarian logistics”, “inventory”, “uncertainty”, “disruption”, “disaster relief”, “materials handling” were explored in the title, keywords and abstract.

3.3 Inclusion and Exclusion Criteria

Inclusion Aspects. The scope of the literature review presented in this paper includes analytical and empirical academic publications such as peer-reviewed papers, conference proceedings with full-paper and dissertations because of their academic relevance. All of the references used for this research are related to inventory management decisions and models in humanitarian logistics, during disaster relief, in the uncertainty of demand or supply and with disruption; trying to meet most of the particular characteristics of the pre or post-disaster scenario.

The works considered are from 2004 to 2015, this is justified by the fact that the increase of the humanitarian logistics academic research potentially increased due to the Asian tsunami in that year [3][12].

Exclusion Aspects. Manuals, books, governmental and military reports and editorial opinions were excluded from this research, the inclusion of these references is suggested for future research. Articles concerning solely to provision source selection, supplier development, performance measurement, pricing, routing or facility location was excluded from the investigation. Non-English or Spanish articles also were excluded from the analysis.

3.4 Study Selection

After establishing the scope of this research the boundaries were applied to the databases research. After this compilation a total of 934 documents were found in all databases. In a second filter the duplicates were eliminated and the remaining were compared to the inclusion criteria previously defined. As the articles were reviewed the sample was expanded with other pertinent cited articles. Finally, 70 references met the inclusion and exclusion criteria, these are the ones analysed and categorized in this research. The complete list of references is included in Appendix I.

3.5 Category Selection

The categories used to classify the literature are shown in Figure 1 detailed below. Four new classification criteria are proposed due to the specific characteristics of the inventory management field, while the rest were used in previous literature reviews. [13] [14][15]

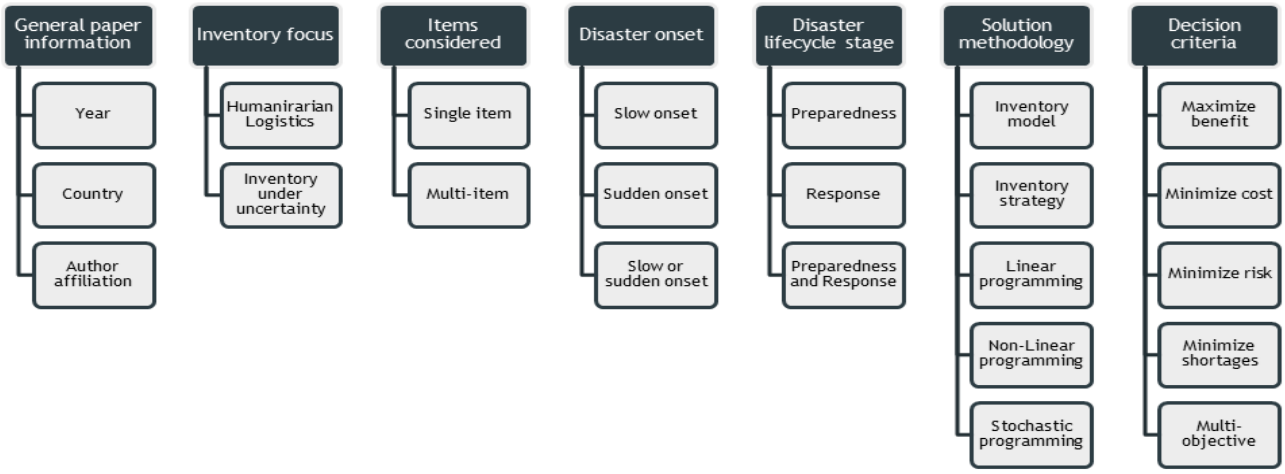

Fig. 1. Classification framework

4 Results

4.1 General Paper Information

Table 1 ranks the top authors of the publications considered for the review, all of them with at least three issues. The highest ranking is Emmett J. Lodree Jr. from the University of Alabama. USA represents three out of four of the top ranked authors in this field.

Table 1. Top Authors' General Information [a] (At Least Three Papers).

Author	Author affiliation	Country	Number of Publications	References
Lodree	University of Alabama	USA	5	Lodree Jr & Taskin (2008), Taskin & Lodree (2010) Lodree Jr (2011), (Taskin & Lodree (2011), Lodree, Ballard, & Song (2012)
Ozbay	The State University of New Jersey	USA	4	Ozbay & Ozguven (2007), Ozguven & Ozbay (2012), Ozguven & Ozbay, (2013), Ozguven & Ozbay (2015)
Ozguven	The State University of New Jersey	USA	4	Ozbay & Ozguven (2007), Ozguven & Ozbay (2012), Ozguven & Ozbay, (2013), Ozguven & Ozbay (2015)
Taskin	ASELSAN, Inc.	Turkey	3	Lodree Jr & Taskin (2008), Taskin & Lodree (2010), Taskin & Lodree (2011)

[a.] According to the information obtained in the databases specified in Material Collection section.

4.2 Inventory Focus

Fig. 2 shows the publication distribution per year according to the inventory focus. The documents were divided in two categories by the approach they had in the presented models. The first category, which is represented by the blue bars, is focused in models applied to the Humanitarian Logistics context while the second category, represented by the orange bars, is applied to the commercial context but resembles some of the humanitarian features.
The publications show a crescent tendency and a significant emphasis in 2011, then they decrease having an average of 9.5 publications per year in the past four years.

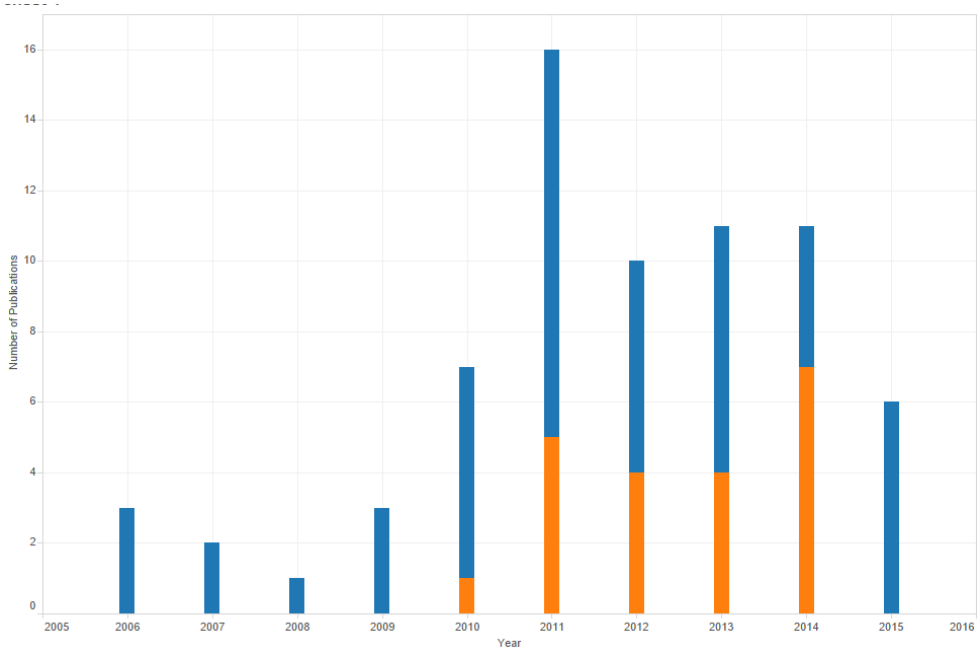

Fig. 2. Annual Paper Distribution by Inventory Focus

4.3 Disaster Onset and Lifecycle Stage

In Fig. 3 the papers that are focused in HL by the previous classification are divided by the stage of the disaster lifecycle they could be applied, the stages that have been proposed throughout the literature are; Mitigation, Preparedness, Response and Recovery. The stages of Mitigation and Preparedness correspond to the planning before the disaster while the stages of Response and Recovery are the reaction after the disaster occurs. In the publications analyzed the stages included were Preparedness, with inventory pre-positioning in most cases, Response, or models including both stages.

These papers were also classified in the type of onset that they are focused on; according to [2] the slow onset disasters are the ones that can be somehow predicted and people can react to them like hurricanes, floods or wars. In the other hand the sudden onset disasters are the ones that do not allow any reactions like earthquakes or terrorist attacks.

In this case the literature has clearly focused more to the response stage. In the case of the disaster onset, the sudden appearance disasters are the ones that have been more studied, followed by models that intend to develop models applicable to both, slow and sudden onset disasters.

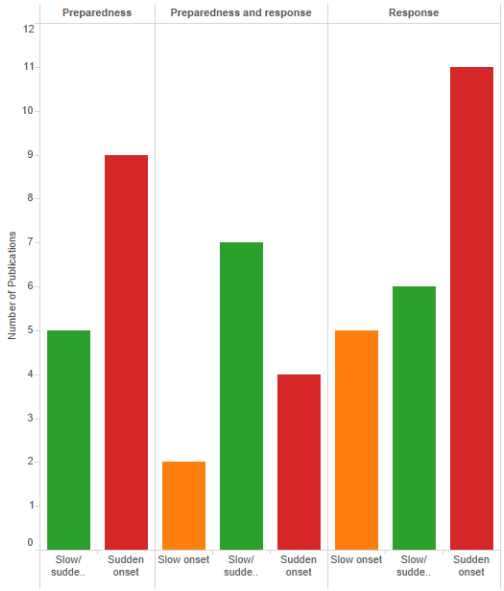

Fig. 3. Number of Publications by Disaster Stage and Disaster Onset

4.4 Items Considered

Table II shows the classification of exclusively the publications that develop an inventory model or strategy, either for HL or for uncertainty in inventories; this excludes the works with qualitative analysis. The documents are divided according to the number of different types of items considered in their model.

In the literature reviewed most of the models contemplate a single item in both of the inventory focus, Humanitarian Logistics and Commercial inventories under uncertainty. However, the difference is more notorious in the inventory models under uncertainty, while in the HL models have more development considering multiple items in their models and strategies.

Table 2. Publications by Items Considered and Focus

Inventory Focus	Single-item	Multi-item
Humanitarian Logistics	26	20
Inventory under uncertainty	18	3

4.5 Solution Methodology and Decision Criteria

This classification as well as the previous only includes the works that propose a model or inventory strategy. It divides the documents by the goal they pursue with the model and the methodology with which were solved.

The findings presented in Fig. 4 show that the models developed are mostly focused in minimizing costs independently of the field that are applied, this followed by multi-criteria approach.

The solution methodology that has been more explored is the stochastic programming, this can be due to the stochastic nature of some of the variables involved, e.g. demand or supply. This is methodology is followed by the linear programming approach.

	Decision Criteria				
Methodology	*Maximize benefit*	*Minimize cost*	*Minimize risk*	*Minimize shortages*	*Multi-objective*
Inventory models		Lodree Jr (2011) Lodree Jr & Taskin, 2008; Masih-Tehrani, Xu, Kumara, & Li (2011) Masih-Tehrani et al. (2011) Ozbay & Ozguven (2007) Schmitt & Snyder (2012) Wang, Li, Liang, Huang, & Ashley (2015) Xanthopoulos, Vlachos, & Iakovou (2012)		McCoy & Brandeau (2011)	Merzifonluoglu & Feng (2014) Yadavalli, Sundar, & Udayabaskaran (2015)
Inventory strategies	Mulyono & Ishida (2014) Tysseland (2009)	Adida, DeLaurentis, & Lawley (2011) Atasoy, Güllü, & Tan (2012) Firouzi, Baglieri, & Jaber (2014) Lewis, Erera, Nowak, & Chelsea C III (2013) Saputra, Pots, de Smidt-Destombes, de Leeuw, & Gaillard (2015) Taskin & Lodree (2010)	Hu & Motwani (2014) Kim & Dwyer (2003) Knemeyer, Zinn, & Eroglu (2009)		
Linear programming	Altay (2012) Coffrin, Van Hentenryck, & Bent (2011)	Beamon & Kotleba (2006a) Beamon & Kotleba (2006b) Darwish, Abdulmalek, & Alkhedher (2013) DeCroix (2013) Huang, Li, & Omitaomu (2011) Rawls & Turnquist (2012) Renkli & Duran (2015) Salas, Cárdenas, & Zhang (2012) Sarder & Iqbal (2013)	Giri (2011)	Akkihal (2006) Rottkemper, Fischer, & Blecken (2012)	Duran, Gutierrez, & Keskinocak (2011) Jaska, Reyes, & Man (2013) Rottkemper, Fischer, Blecken, & Danne (2011)
Non-Linear programming	Qiu & Shang (2014)	Hishamuddin, Sarker, & Essam (2012)			Campbell & Jones (2011) Mirzapour Al-E-Hashem, Malekly, & Aryanezhad (2011)
Stochastic programming	Li, Zhang, & Tang (2014)	Ahiska, Appaji, King, & Warsing (2013) Lodree, Ballard, & Song (2012) Ozguven & Ozbay (2015) Ozguven & Ozbay (2012) Ozguven & Ozbay (2013) Rawls & Turnquist (2010) Schmitt, Snyder, & Shen (2010) Silbermayr & Minner (2014) Song, Dong, & Xu (2014) Taskin & Lodree (2011) Van Wyk (2010) Van Wyk, Bean, & Yadavalli (2011) Zhu, Gu, & Gu (2011)		Garrido, Lamas, & Pino, (2015)	Bozorgi-Amiri, Jabalameli, & Al-e-Hashem (2013) Davis, Samanlioglu, Qu, & Root (2013) Hong, Lejeune, & Noyan (2014) Klibi, Ichoua, & Martel (2013) Kunz, Reiner, & Gold (2014) Liu & Zhao (2012) Mete & Zabinsky (2010) Noyan (2012) Peng, Peng, & Chen (2014) Salmerón & Apte (2010)

Fig. 4. Solution Methodology and Decision Criteria Analysis

4.6 Critical Issues in HL Inventories

As presented in Section II there are critical issues that differentiate the commercial and humanitarian inventories. Table 3 presents the literature included in the analysis compared with the issues proposed previously.

With this table we can conclude that the models with No Repetitive Inventories along the time and the urgency of getting the supplies to the affected area are being considered in most of the documents of the review.

In contrast, the features that are being less considered are the Human Resources Variability, the different Political and Cultural matters and Expiration and Obsolescence. The less considered features are also the more difficult to quantify because they are very variable features and they have a qualitative nature.

Table 3. Decision Criteria vs. Critical Issues in HL Inventories Analysis

Decision criteria	**Critical issues in HL**										
	1	2	3	4	5	6	7	8	9	10	11
Maximize Benefit											
Altay (2012)	✓			✓	✓	✓				✓	✓
Coffrin, Van Hentenryck, & Bent (2011)	✓				✓	✓				✓	
Li, Zhang, & Tang (2014)		✓							✓		
Mulyono, Nur Budi & Ishida, Yoshiteru (2014)	✓	✓		✓	✓	✓				✓	
Qiu & Shang (2014)		✓							✓		
Tysseland (2009)	✓						✓		✓		✓
Minimize cost											
Adida, DeLaurentis, & Lawley (2011)	✓		✓		✓						
Ahiska, Appaji, King, & Warsing (2013)		✓			✓			✓			
Atasoy, Güllü, & Tan (2012)		✓		✓				✓			
Beamon & Kotleba (2006a)	✓	✓			✓		✓				✓
Beamon & Kotleba (2006b)	✓	✓			✓		✓				✓
Darwish, Abdulmalek, & Alkhedher (2013)		✓				✓					
DeCroix (2013)		✓		✓							
Firouzi, Baglieri, & Jaber (2014)		✓		✓		✓		✓			
Hishamuddin, Sarker, & Essam (2012)		✓					✓				
Huang, Li, & Omitaomu (2011)	✓			✓	✓			✓			
Lewis, Erera, Nowak, & Chelsea C III (2013)		✓		✓				✓			
Lodree Jr (2011)	✓		✓			✓		✓			
Lodree Jr & Taskin (2008)	✓	✓	✓		✓						
Lodree, Ballard, & Song (2012)	✓	✓	✓					✓		✓	
Masih-Tehrani, Xu, Kumara, & Li (2011)		✓		✓				✓			
Ozbay & Ozguven (2007)	✓	✓	✓		✓	✓		✓			
Ozguven & Ozbay (2015)	✓	✓				✓		✓			
Ozguven & Ozbay (2012)	✓	✓	✓	✓	✓	✓					
Ozguven & Ozbay (2013)	✓	✓	✓		✓	✓		✓			
Rawls & Turnquist (2010)	✓	✓				✓	✓		✓	✓	
Rawls & Turnquist (2012)	✓	✓				✓	✓		✓	✓	
Renkli, Ç. Duran, S. (2015)	✓		✓							✓	
Salas, L. C., Cárdenas, M. R., & Zhang, M. (2012)	✓	✓	✓						✓		
Saputra, Pots, de Smidt-Destombes, de Leeuw, & Gaillard (2015)	✓				✓				✓		✓
Sarder & Iqbal (2013)	✓	✓	✓					✓			
Schmitt, Snyder, & Shen (2010)		✓		✓							
Schmitt & Snyder (2012)		✓		✓				✓			
Silbermayr & Minner (2014)		✓		✓				✓			
Song, Dong, & Xu (2014)				✓				✓			
Taskin & Lodree (2011)	✓					✓		✓			✓
Taskin & Lodree (2010)	✓							✓			✓
Van Wyk (2010)	✓		✓	✓	✓				✓		✓
Van Wyk, E., Bean, W.L., & Yadavalli, Sarma (2011)		✓		✓		✓					

Wang, X., Li, F., Liang, L., Huang, Z., & Ashley, A. (2015)	✓	✓			✓			✓			
Xanthopoulos, Vlachos, & Iakovou (2012)		✓						✓			
Zhu, Gu, & Gu (2011)		✓		✓		✓					
Minimize risk											
Giri (2011)								✓			
Hu & Motwani (2014)				✓				✓			
Kim & Dwyer (2003)				✓				✓			
Knemeyer, Zinn, & Eroglu (2009)	✓	✓								✓	
Minimize shortages											
Akkihal (2006)	✓									✓	✓
Garrido, Lamas, & Pino (2015)	✓	✓				✓		✓		✓	
McCoy & Brandeau (2011)	✓	✓	✓				✓	✓			
Rottkemper, Fischer, Blecken, & Danne (2011)	✓		✓							✓	
Multi-objective											
Bozorgi-Amiri, Jabalameli, & Al-e-Hashem (2013)	✓		✓	✓		✓		✓		✓	✓
Campbell, A. M. (2010)	✓								✓	✓	
Davis, Samanlioglu, Qu, & Root, (2013)	✓	✓	✓					✓	✓	✓	
Duran, Gutierrez, & Keskinocak, (2011)	✓	✓				✓	✓	✓		✓	
Hong, Lejeune, & Noyan (2014)	✓	✓	✓							✓	
Jaska, Reyes, & Man (2013)	✓	✓			✓			✓		✓	
Klibi, Ichoua, & Martel (2013)	✓	✓				✓		✓	✓	✓	
Kunz, N., Reiner, G., Gold, S. (2014)	✓	✓					✓			✓	
Liu, M., Zhao, L. (2011)	✓									✓	
Merzifonluoglu & Feng, (2014)				✓	✓			✓			
Mete & Zabinsky (2010)	✓	✓	✓			✓				✓	
Mirzapour Al-E-Hashem, Malekly, & Aryanezhad (2011)			✓	✓				✓			
Noyan, N (2012)		✓				✓				✓	
Peng, M., Peng, Y., & Chen, H. (2014)	✓	✓					✓				
Rottkemper, Fischer, & Blecken (2012)	✓	✓	✓			✓				✓	
Salmerón & Apte (2010)	✓	✓	✓							✓	
Yadavalli, V. S. S., Sundar, D. K., & Udayabaskaran, S. (2015)		✓			✓	✓			✓		

5 Conclusions and Future Research Directions

This paper presented a set of unique characteristics of inventory management in situations humanitarian help is required, such as great impact disasters, wars, hunger and others. The differences between commercial or classical inventories and humanitarian inventories are significant but not always well understood which limits appropriate research in the field.

With the particularities in the humanitarian inventories presented, a literature review was also presented, it included 70 publications with the aim of describe the state of the art of inventory management in humanitarian operations as well as models that can be applied in those instances. These publications were reviewed and classified in seven categories, and matched with the features first described.

The systematic review of the literature revealed the gaps in the knowledge on inventory management. For instance, the analysis has suggested some conclusions:

- Inventory management in humanitarian operations is a field that just started being developed by the academy since less than ten years and still has a wide opportunity area.
- The majority of the contributions in this field come from the US therefore, an increase in the contribution of the Latin American, European and Asian context will help enormously to the enrichment of the knowledge in this field.
- The inventory management developed in the models not always specifies the echelon in which it could be applied, i.e. collection points, intermediate warehouses or distribution points. Considering the inventory operations along the supply chain have different activities and goals an important research line would be the specialization of the models according to the special inventory studied.
- The different models developed tend to consider a single item; this states very good management models. However, in the case of a disaster or other humanitarian case many different items must be collected and delivered, therefore the necessity of more models considering multiple different items in their inventories.
- In few of the models developed the qualitative factors, such as cultural or human resources matters, are considered. Factors that in real operations can define the success of the supplies' delivery. Considering these type of features can make the models more realistic and applicable.

A complete understanding of the special considerations in the inventory management and the recognition of the state of art in the field can help substantially the decision makers to improve the development of their warehouses and thus the global performance of the humanitarian supply chain.

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