A performance measurement system for the evaluation of humanitarian supply chains

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Abstract
The authors develop and implement a holistic and applicable performance measurement system to measure the performance of humanitarian supply chains during both disaster situations and development. The system could help no-profit organization to make better decisions, improve their performance and provide accountability.

Keywords: humanitarian supply chain, performance measurement, key performance indicator, experimental evidences

Introduction
Since 1975 the total number of natural and technological disasters increased, It is expected a steadily increase of five-fold times for the number of natural disasters over the next fifty years (Thomas and Kopczak 2007). Humanitarian logistics operations are characterized by unpredictability of disasters, lack of institutional learning, poor manual logistics processes, highly employee salary costs, as well as poor fragmented technology (Thomas 2008; Thomas and Kopczak 2005). In short, humanitarian organizations are faced with logistics complexity, destabilized infrastructure and environment and the humanitarian organization staff works in an extremely chaotic environment (Cassidy 2003; Regattieri and Santarelli 2013). According to Thomas and Kopczak (2005), the focus of humanitarian logistics is the process of planning, implementing and controlling the efficient, cost effective flow and storage of goods and materials, as well as related information from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. Nevertheless, the significant increase of natural disasters, complex and cost intensive humanitarian logistics operations,

responsibility, and reporting towards to donors and beneficiaries are reasons for humanitarian organizations to become more efficient in their operations. For an effective supply chain management in particular humanitarian supply chain management performance measurement and indicators are crucial. The humanitarian organizations are featured with challenges in developing suitable and common performance measures and indicators. Then in practice 55% of humanitarian organization do not monitor and report any performance measurement indicators, 25% declare to control few indicators and 20% measure performance consistently (Blecken 2010). The main target of performance measurement and suitable financial and non-financial indicators is to inform decision makers at the strategical, tactical and operational level in producing of high quality goods, processes and services (Gunasekaran and Kobu 2007) during humanitarian operations relief in case of disaster (Gunasekaran and Kobu 2007; Long 1997). Performance measurement is fundamental for improvement (Kaplan 1990), for making decision (Long 1997), for simplifying communication between supply chain actors and increase transparency of the supply chain and logistics processes (Gunasekaran and Kobu 2007).

This research paper attempts to determine a set of suitable financial and non-financial indicators for humanitarian supply chains and logistics. The authors have developed a performance measurement system and implemented it with five humanitarian organizations in order to discuss the first experimental evidences.

State of the art on performance measurement in humanitarian supply chains
Neely et al. (1995) defined performance measurement as the process to quantify the efficiency and effectiveness of an operation. Although there is an increasing interest in humanitarian logistics topic, performance measurement has been considered rarely (de Leeuw 2010; Kovács and Spens 2007; Tomasini and van Wassenhove 2009). In the period from 1970 till 2012 only 23 publications has been found, and only 12 of these deal with performance measurement systems and metrics.

Chang and Nojima (1999) developed a post-disaster performance measurement system and used them to the urban rail and high transportation systems in Japan and facilitated the understanding the effects of historic disasters and preparing for future hazards. Helbing and Kühnert (2003) focused by using a mathematical model on evaluating the impact of optimization measures or failures on the system and the investigation of catastrophes, in particular to the temporal development of disasters (catastrophe dynamics). Medina-Borja et al. (2007) presented one of the first large-scale implementations of data envelopment analysis (DEA) and defined a conceptual model to measure performance in no-profit sector. In the same year Moe et al. (2007) proposed a balanced scorecard (BSC) approach to apply to natural disasters, in order to maximize the possibilities of desired outcomes from projects. The approach was tested on a real disaster. In 2008 Beamon and Balcik discussed the two different supply chain types namely humanitarian and commercial supply chain and adapted an existing performance measurement framework developed for supply chain considering the unique characteristics of relief chain. A significance increase of interest in the topic performance measurement in humanitarian logistics and humanitarian supply chain can be seen in 2009. Blecken et al. (2009) developed a process reference model for humanitarian supply chains to support humanitarian organizations in several activities, from which the measurement of their performance. A top-down approach was followed in which modular process element were developed and relevant performance measures were identified. Lin et al. (2009) demonstrated how to apply the model developed to a case study. A series of sensitivity analysis was conducted in the paper to provide insights to the influence of

various parameters settings to the performance of a disaster relief operation, such as the depot location, the number of vehicles, and the number of clusters chosen. Mwenka and Levis (2009) elaborated a study that examines three theoretical perspectives. These can be utilized to connect the different dimensions of board performance and organizational performance. Schulz and Heigh (2009) described the tool developed by federation of Red Cross and Red Crescent societies to guide and monitor continuously the performance of humanitarian organizations. Van der Laan et al. (2009) identified a number of necessary conditions to implement an effective measurement system for the performance of humanitarian supply chains. They realized a case study to investigate whether these conditions were met or not. De Leeuw (2010) presented an approach in order to develop a reference mission map based on a method in industry. Subsequently the author analysed four mini case studies to demonstrate each of the four perspective of the BSC. Based on a study, Rongier et al. (2010) proposed a method assisting the humanitarian actors in their choices while carrying out a performance evaluation of the activities during the crisis in the response process.

Humanitarian supply chain performance measurement system
The measurement of performance in humanitarian supply chains has become vital for all organizations involved in disaster management (Beamon and Balcik 2008). Since logistics is central to relief operations, the authors have defined a performance system focusing on humanitarian supply chains during both disaster situations and development. The system can be used as a basis to measure performance of humanitarian organizations in terms of response time, service quality, and technical and cost efficiency. The authors have identified five categories and for each of them several KPIs, both quantitative and qualitative, financial and no-financial.. It is important to specify that the indicators are relative to one specific project in which the humanitarian organization is involved.

a) Response time
In a humanitarian supply chain, time is the most critical measure of performance. Many factors can contribute to relief chain response time, including relief organizations assessment, procurement and delivery strategies, supplier location, and transportation choice. Five are the KPIs defined in this category:

▪ Duration of the project. It is a quantitative, no-financial index measured by the number of month of the project's duration.
▪ Average response time. It is a quantitative, no-financial index, defined as the average response time between the onset of the disaster and the arrival time of organization's first supplies, both personnel and goods, at the disaster area. It is measured by the average number of days to reach the disaster area.
▪ Delivery date reliability. It is a quantitative, no-financial index that measures the efficiency of the humanitarian organizations in terms of delivery date both in the first aid (< three months) and at steady-state (> three months). It is calculated by:
$$DDR = \frac{\text{Number of deliveries on time}}{\text{Total number of deliveries}}$$
▪ Goods-to-delivery time. It is a quantitative, no-financial index, defined as the time between when goods are purchased by the organization and when they arrive at the disaster area. The index is measured as the average number of days between delivery times of all goods provided to the disaster area and is divided in three sub-indices: time to purchase, time to transport and time to deliver goods to the staging area.
▪ Presence of organization's warehouse in loco. It is a quantitative, no-financial index that

expresses the presence of organization's warehouse with prepositioned materials in a radius of 200 km around the disaster area.

b) Reliability / Flexibility

In a humanitarian supply chain, the ability to change according to external conditions (e.g. number and different typologies of goods to deliver, delivery time of goods, etc.) as well as the reliability in delivery date and quality, assumes a fundamental role. Three are the KPIs defined in this category:

- Volume flexibility. It is a qualitative index, defined as the organization's ability to change the number of goods sent to the disaster area, according to different magnitudes of disasters. It is evaluated using a range from 1 (very low) to 5 (very high).
- Mix flexibility. It is a qualitative index defined as the organization's ability to change the variety of goods sent to the disaster area, according to the necessities of people. It is evaluated using a range from 1 (very low) to 5 (very high).
- Percentage of prepositioned goods. It is a quantitative, no-financial index, defined as the percentage of goods that are prepositioned in the organization's warehouses on the total number of goods. The index is divided in three sub-indices and it is calculated for both drugs and no-drugs:
  - The percentage of prepositioned goods at regional level, calculated by:
  $$\text{PGL} = \frac{\text{Number of prepositioned goods at local level}}{\text{Total number of goods}}$$
  - The percentage of prepositioned goods at international level, calculated by:
  $$\text{PGI} = \frac{\text{Number of prepositioned goods at international level}}{\text{Total number of goods}}$$
  - The percentage of no-prepositioned goods, calculated by:
  $$\text{NPG} = \frac{\text{Number of no} - \text{prepositioned goods}}{\text{Total number of goods}}$$

c) Cooperation / Standardization

In humanitarian supply chain the cooperation and exchange of data between actors involved in a disaster are indispensable in order to effectively respond to the emergency. Moreover, the standardization of procedures could accelerate and improve the resolution of the disaster. Three are the KPIs defined in this category:

- Degree of information sharing. It is a qualitative index that measures the degree of information sharing between actors belonged to the organization and involved in a disaster. It is evaluated using a range from 1 (very low) to 5 (very high).
- Degree of cooperation. It is a qualitative index that measures the degree of cooperation between actors belonged to the organization and involved in a disaster. It is evaluated using a range from 1 (very low) to 5 (very high).
- Degree of standardization. It is a qualitative index that measures the degree of standardization of procedures used during the resolution of the disaster. It is evaluated using a range from 1 (very low) to 5 (very high).

d) Beneficiaries and donors satisfaction

The financial donors and mainly the beneficiaries of the humanitarian help are the most important stakeholders for no-profit organizations. Humanitarian organizations should act according to the will of the donors and mainly should do the best for the beneficiaries, helping them during both the emergency and the restoration of the normalcy. Seven are the KPIs defined in this category:

- Number of relief workers. It is a quantitative, no-financial index that measures the number of

relief workers employed in the resolution of the disaster, both at national and international level.

- Percentage of people engaged on dispensing aid. It is a quantitative, no-financial index that measures the percentage of people engaged on dispensing aid (e.g. doctors and health personnel, logisticians, etc.). It is calculated as:

$$PDA = \frac{\text{Number of workers engaged on dispensing aid}}{\text{Total number of workers}}$$

- Total dollars spent. It is a quantitative, financial index that measures the organization in financial terms and it is expressed by two sub-indices:
  - Dollars given by institutional donors;
  - Dollars given by private donors.

- Number of people helped. It is a quantitative, no-financial index that measures the efficiency of the organization in terms of people helped (both direct and indirect beneficiaries).

- Donors' auditing. It is a quantitative, no-financial index that expresses if donors are used to monitor the work of organization's employees.

- Spending capacity. It is a quantitative, financial index that measures the ability of the organization to respect the account of money requested to donors. It is calculated by:

$$SC = \frac{\text{Dollars spent given by institutional donors}}{\text{Total dollars requested to institutional donors}}$$

- Satisfaction level. It is a qualitative index that measures the perception of the satisfaction level of donors by organizations. It is evaluated using a range from 1 (very low) to 5 (very high).

e) Cost performance

Although the costs are not the predominant resource metrics for humanitarian supply chain, is important to evaluate them. Due to the unpredictable demand, the evaluation and control of costs are difficult. This kind of performance indices can be evaluated only after the disaster occurrence and restoration of normalcy. Five are the KPIs defined in this category:

- Cost of goods. It is a quantitative, financial index that measures the percentage of the total cost of goods sent to the disaster area during the emergency situation on the total cost of the project. It is calculated as:

$$CG = \frac{\text{Total cost of goods}}{\text{Total dollars spent}}$$

- Transportation cost. It is a quantitative, financial index that measures the incidence of the total transportation cost during the whole period in which the organization stays in the disaster area on the total cost of the project. The index is divided in three sub-indices:
  - Incidence of the total transportation cost by air, calculated by:

$$TTA = \frac{\text{Total transportation cost by air}}{\text{Total dollars spent}}$$

  - Incidence of the total transportation cost by sea, calculated by:

$$TTS = \frac{\text{Total transportation cost by sea}}{\text{Total dollars spent}}$$

  - Incidence of the total transportation cost by truck, calculated by:

$$TTT = \frac{\text{Total transportation cost by truck}}{\text{Total dollars spent}}$$

- Warehousing cost. It is a quantitative, financial index that measures the percentage of the total warehousing cost for storing goods in the surroundings of the disaster area on the total cost of the project. It is calculated as:

$$WC = \frac{\text{Total warehousing cost}}{\text{Total dollars spent}}$$

- Percentage of claims. It is a quantitative, no-financial index that measures the percentage of claims regarding both drugs and no-drugs that the organization makes versus its suppliers. It is calculated as:

$$PC = \frac{\text{Number of orders claimed/year}}{\text{Number of orders/year}}$$

- Percentage of goods not distributed. It is a quantitative, no-financial index that measures the percentage of goods stocked but not distributed to people. The index refers to both drugs and no-drugs and it is calculated as:
  - Percentage of drugs not distributed, calculated by:

$$DND = \frac{\text{Number of drugs not distributed}}{\text{Total number of goods}}$$

  - Percentage of no-drugs not distributed, calculated by:

$$NDND = \frac{\text{Number of no} - \text{drugs not distributed}}{\text{Total number of goods}}$$

Implementation of the performance measurement system

In order to evaluate the feasibility of the performance measurements system, the authors have implemented it with five humanitarian organizations. They have confirmed the lack and at the same time the need a performance evaluation system, since three out five have declared not to have a KPIs panel to evaluate performance system. In order to clarify the data, H_2 could be defined a small humanitarian organization, while the others are large humanitarian organizations working at global level. Next paragraphs will discuss each category of the KPIs system for the five humanitarian organizations interviewed (Table 1-5).

a) Response time (Table 1)

KPIs	Formula	H_1	H_2	H_3	H_4	H_5	Average	Dev Std
Duration of the project	Number of months	7	12	36	18	36	21.8	13.5
Average response time	Average number of days (personnel)	1	15	1	0-2	2	4	6.2
	Average number of days (goods)	5	60	1.5	Not Available	7	18.4	27.8
Delivery date reliability	*First aid (< 3 months)* $\frac{\text{Number of deliveries on time}}{\text{Total number of deliveries}}$	< 50%	30%	40-50%	90%	60%	55%	22.4%
	Steady-state (> 3 months) $\frac{\text{Number of deliveries on time}}{\text{Total number of deliveries}}$	80%	70%	60-70%	90%	90%	79%	11.4%
Goods-to-delivery time	Average number of days to purchase the order	2	60	15-90	Not Available	15	12.5	16.9
	Average number of days to transport goods from the organizations' warehouse to the disaster area	2-3	3	1.5	3-7			
	Average number of days to deliver goods to the staging area	7		7-15	3-7			
Presence of the warehouse in loco	Yes/No	Yes	Yes	No	Yes	Yes	-	-

The collected data show the significant difference between large and small humanitarian organizations: the first ones are able to quickly respond to emergencies since they have a major number of means, both technical and economics. This is confirmed by the minor number of days

that large organizations spent to reach disaster areas and the major percentage of deliveries on time. Although almost all the organizations (four out five) declared to have a warehouse in the surroundings of the disaster area in order to faster achieve people, large organizations are favoured in the time employed to purchase and transport goods, and stock the warehouse. Because of the low number of interviewed humanitarian organizations, it is necessary to confirm and better investigate these first evidences, especially for small organizations.

b) Reliability / Flexibility (Table 2)

KPIs	Formula		H_1	H_2	H_3	H_4	H_5	Average	Dev Std
Volume flexibility	[1-5] (1 very low; 5 very high)		5	3	4	5	4-5	4.25	0.96
Mix flexibility	[1-5] (1 very low; 5 very high)		5	4	4	5	5	4.6	0.55
Percentage of prepositioned goods	Drugs	$\frac{\text{Number of prepositioned goods at local level}}{\text{Total number of goods}}$	3.5%	50%	0%	0%	60%	40.7%	38.5%
		$\frac{\text{Number of prepositioned goods at international level}}{\text{Total number of goods}}$	31.5%	0%	0%	90%	20%	12.9%	15.6%
		$\frac{\text{Number of no} - \text{prepositioned goods}}{\text{Total number of goods}}$	65%	50%	100%	10%	20%	58.8%	33.3%
	No-Drugs	$\frac{\text{Number of prepositioned goods at local level}}{\text{Total number of goods}}$	10%	0%	0%	0%	20%	7.5%	9.6%
		$\frac{\text{Number of prepositioned goods at international level}}{\text{Total number of goods}}$	40%	0%	10-15%	85%	20%	18.3%	16.7%
		$\frac{\text{Number of no} - \text{prepositioned goods}}{\text{Total number of goods}}$	50%	0%	25-30%	15%	60%	35%	26.5%

From the data shown in Table 2, it is possible to note that all organizations have a considerable flexibility in terms of volume and mix of products. This is an important value since humanitarian organizations have to face not announced disasters and emergency in countries difficult to reach. According to Table 3, the prepositioned goods do not depend on the size of the humanitarian associations, but on the internal management of the humanitarian association (for example, someone declared to use the virtual stock for several goods).

c) Cooperation / Standardization (Table 3)

KPIs	Formula	H_1	H_2	H_3	H_4	H_5	Average	Dev Std
Degree of information sharing	[1-5] (1 very low; 5 very high)	3	4	4	4	4-5	3.75	0.5
Degree of cooperation	[1-5] (1 very low; 5 very high)	3	2	3	4	4-5	3	0.82
Degree of standardization	[1-5] (1 very low; 5 very high)	2	4	2	5	4	3.25	1.5

As well as in the previous section, the degree of information sharing and cooperation, and the presence of standard procedures in order to operate in the field, do not depend on the size of the humanitarian associations, but on their ability to coordinate actors, share information, and data and organize the work. All the organizations look to be careful to share data and collaborate with each other. Information sharing and cooperation between actors involved in a disaster are vital, since relief workers have to collaborate and exchange data, if they want to reach the main purpose of their mission: saving the major number of people as possible.

d) Beneficiaries and donors satisfaction (Table 4)

KPIs	Formula	H_1	H_2	H_3	H_4	H_5	Average	Dev std
Number of relief	Number of relief workers at	1,000	40	400-500	97	250	367.4	287.7

workers	national level							
	Number of relief workers at international level	100	5	50-60	56	400	123.2	271.4
Percentage of people engaged on dispensing aid	$\dfrac{\text{Number of workers engaged on dispensing aid}}{\text{Total number of workers}}$	55-60%	75%	60%	60%	70%	64.6%	7.5%
Total dollars spent	Dollars given by institutional donors	40 M$	1.25 M€	20 M$	67 M$	95 M$	44.8 M$	37.1 M$
	Dollars given by private donors	1 M$	0	5M$	N/A	5 M$	2.75 M$	2.63 M$
Number of people helped	Number of people helped	100,000-120,000	180,000	2.15 M	1.5 M	1 M	988,000	871,246
Donor's auditing	Yes/No	Yes	Yes	Yes	Yes	Yes	-	-
Spending capacity	$\dfrac{\text{Dollars spent given by institutional donors}}{\text{Total dollars asked to institutional donors}}$	100% (±5-7%)	100%	60%	85%	100%	89%	17.5%
Satisfaction level	[1-5] (1 very low; 5 very high)	4-5	4	3	4-5	4	3.67	0.58

From Table 4, it is possible to notice the difference between large and small humanitarian organizations, relating to major number of workers (both national and international staff), dollars given by donors, and number of people helped (both direct and indirect beneficiaries). As well as in *Response time* category, this data has to be confirmed because of the low number of interviewed organizations. All the organizations declared that their donors always monitor the work of organization's employees. One of the donors' KPIs is the spending capacity that is the ability of the organization to spend the same amount of dollars it asked donors. Three organizations out five stated to receive more than what is asked, thanks to private donors. This data is of fundamental importance for donors in order to understand the way in which their money is spent.

e) Cost performance (Table 5)

KPIs	Formula	H_1	H_2	H_3	H_4	H_5	Average	Dev Std
Cost of goods	$\dfrac{\text{Total cost of goods}}{\text{Total dollars spent}}$	40%	60%	25%	18%	60%	40.6%	19.4%
Transportation cost	$\dfrac{\text{Total transportation cost by air}}{\text{Total dollars spent}}$	10-20%	Not available	2-4%	0.25%	15%	6.6%	6.5%
	$\dfrac{\text{Total transportation cost by sea}}{\text{Total dollars spent}}$	3-4%	Not available					
	$\dfrac{\text{Total transportation cost by truck}}{\text{Total dollars spent}}$	6-7%	Not available					
Warehousing cost	$\dfrac{\text{Total warehousing cost}}{\text{Total dollars spent}}$	0.6%	1-2%	1%	Not available	2.5%	1.4%	0.8%
Percentage of claims	$\dfrac{\text{Number of orders claimed/year}}{\text{Number of orders/year}}$	2-3%	0%	2-3%	10-15%	5%	4.5%	4.8%
Percentage of goods not distributed	$\dfrac{\text{Number of drugs not distributed}}{\text{Total number of goods}}$	2-3%	0%	10-15%	0%	Not available	6.3%	5.2%
	$\dfrac{\text{Number of no}-\text{drug goods not distributed}}{\text{Total number of goods}}$	10-15%	0%		10%			

Despite the cost to purchase, transport and stock goods are similar for all the organizations, they depend on the size of the humanitarian associations, since large and global ones have a major number of ways to purchase products, find the right transport and the closest warehouse to use for the stock. This data has to be confirmed and better evaluated because of the low number of interviewed organizations, especially concerning the small ones.

Even though all the organizations have declared that money is not important during a disaster, the costs have to be considered. Another important data is the percentage of goods not distributed at the end of a disaster: all the organizations declared to re-distributed products, for

example using them during another emergency in the same country or in another.

Conclusions and further research

Humanitarian logistics is a recent discipline dealing with the supply and distribution of goods and/or services during emergency situations, and concerns the distribution of aid following natural and manmade disasters, as well as in complex emergencies including war and conflict situations (Jahre and Jensen 2010).

Although the humanitarian logistics topic is increasing interesting both from practitioners and academics, a depth analysis on performance measurements literature in humanitarian supply chains has revealed the lack of standards and indicators used to evaluate and measure humanitarian organizations during an emergency response (de Leeuw 2010; Kovács and Spens 2007; Tomasini and van Wassenhove 2009).

In order to evaluate the performance of humanitarian organizations during disaster situations and development, the authors proposed an effective KPIs system focusing on humanitarian supply chain.

The performance measurement system has been divided in five categoriesand for each one the authors defined several KPIs, qualitative and quantitative, financial and no-financial. The system has been implemented with five humanitarian organizations that are global players and act worldwide.

The implementation of the proposed KPIs system has confirmed the low use of performance indices in the humanitarian supply chains (i.e. only two organizations out five declared to have a KPIs panel to evaluate the performance). Through the analysis of the data, it has been possible to observe that the dimension of organizations plays a significant role, in term of response readiness and reliability of deliveries. These first evidences have to be confirmed and better investigated due to the low number of interviewed organizations.

Moreover, the analysis of the humanitarian organizations' answers shows some significant aspects: the logistics costs appear not estimated in the right manner since organizations don't well know the partition of transportation cost, warehousing cost, cost of goods, etc (i.e. costs values are very dispersed among the different organizations). Another significant aspect is the low reliability of organizations in terms of delivery date in the first aid period: this could be explained by the unpredictability of events that do not allow organizations to plan the emergency operation. The low reliability during the first aid period could be caused also by the difficulty to purchase and transport goods to the disaster area. The purchase process appears another area eligible for further investigation. According to the organizations' answers, there is not a specific strategy to preposition goods: some of them stated to preposition goods in a local warehouse, others to have virtual stocks at their suppliers, and others not to preposition goods neither at local level nor at international. These different strategies about the goods prepositioning problem usually are based on the experience of the supply chain managers.

Finally, the organizations declare sufficient degrees of information sharing and cooperation, but a poor degree of the standardization of procedures. The level of satisfaction of donors is considered high or very high.

Further research should focus on the implementation of the performance measurement system with more humanitarian organizations so as to define a complete reference framework on performance indices in humanitarian supply chains. After that, it could be interesting to define "second level KPIs", deriving from the combination of the ones defined in this paper to better evaluate the humanitarian supply chains performance.

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