World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:11, No:2, 2017

Appraisal of Humanitarian Supply Chain Risks Using Best-Worst Method

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Open Science Index, Industrial and Manufacturing Engineering Vol:11, No:2, 2017 publications.waset.org/10006312.pdf

***Abstract*—**In the last decades, increasing in human and natural disaster occurrence had very irreparable effects on human life. Hence, one of the important issues in humanitarian supply chain management is identifying and prioritizing the different risks and finding suitable solutions for encountering them at the time of disaster occurrence. This study is an attempt to provide a comprehensive review of humanitarian supply chain risks in a case study of Tehran Red Crescent Societies. For this purpose, Best-Worst method (BWM) has been used for analyzing the risks of the humanitarian supply chain. 22 risks of the humanitarian supply chain were identified based on the literature and interviews with four experts. According to BWM method, the importance of each risk was calculated. The findings showed that culture contexts, little awareness of people, and poor education system are the most important humanitarian supply chain risks. This research provides a useful guideline for managers so that they can benefit from the results to prioritize their solutions.

***Keywords*—**Best worst method, humanitarian logistics, humanitarian supply chain, risk management.

I. Introduction

HUMANS are constantly exposed to dangers and accidents in their lives. Annual events that take the lives of thousands of people in the world, with hundreds of thousands damages and there are many costs to society. For example, in 2003, an earthquake occurred in the historic city of Bam in Iran. In this catastrophic disaster, approximately 50000 people lost their lives, 30000 people were wounded, and more than 100000 people were left homeless. Over 40 countries and 70 non-governmental organizations (NGOs) provided humanitarian assistance [1].

Immediately after the occurrence of disasters, humanitarian operations are initiated with the intent to prepare quick assistance to victims in different ways such as salvaging those who are wounded, collecting and disposing of corpses, resource allocation, provision of food aid, shelter and medical care, and restoring access to remote locations [2]. To perform this operation, many organizations participate including: government, Red Crescent, the military, aid agencies, donors, NGOs, and private sector companies, so design and operation of a humanitarian supply chain (HSC) to coordinate these organizations and sectors play an outstanding role in achieving an effective and efficient response [3].

According to literature, HSC is defined as the "process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people" [4], [5]. HSC also needs a process for managing the flow of goods, information, and finances from donors to affected people [3], [6], [7].

Delays in delivery of goods or relief action in HSC can cost lives. Hence, efficiency and security in HSC are a key success factor because it ensures the smooth flow of goods and services in a complex SC [2].

There are some risks for every organization and operations that disrupt the assistance to disaster victims. Because of unpredictable nature of events, assessment, evaluation, and SC risk management (SCRM) are turned to a critical issue for humanitarian organizations.

Risk management means recognition, analysis, and economical control of risks or probability of risks which can threat properties and economical incomes of companies. On the other hand, risk management is the same system which is planned to order the confronting operations against indetermination and probable deviation [8]. Hence, risk management can help identify and evaluate risky and unexpected situations and present strategies to reduce the risks. Reducing the probability of HSC risk is important for improving the efficiency of relief operations.

The rest of the paper is organized as follows: Section II reviews the concept of SC, HSC, and risk management of HSC. Section III presents the research methodology. In Section IV, the importance of HSC risks is calculated by BWM technique. Finally, Section V concludes the paper with main contributions.

II. Literature Review

A. Supply Chain (SC)

A SC includes all the steps that directly and indirectly meet customer needs. In the literature, different definitions of SC are represented: according to Christopher [9], a SC is a network of corporations that are participated through upstream and downstream nodes in the various processes and activities that create value in the form of goods and services for the final consumer [10].

A SC consists of all parties involved, directly or indirectly, in fulfilling a customer request. The SC includes not only the

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manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves [11].

In any each organization such as a plant, the SC includes all functions involved in receiving and satisfying a customer order. SC management (SCM) is a fusion of science and art that improves the method of raw materials finding that is needed for firms.

B. Humanitarian Supply Chain (HSC)

HSC is the processes and systems involved in mobilizing people, resources, skills and knowledge to help vulnerable people affected by disaster. HSCs show the extremes of a trend towards more uncertainty and risk prevalent in today's global business SCs [12].

Humanitarian logistics contains a range of activities including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearances [3]. The main goal of HSCs is saving lives and mitigating human suffering [13].

According to the literature of this field, HSC is usually divided into four stages which are [4]:

- ✓ Mitigation: refers to laws and mechanisms that reduce social vulnerability.
- ✓ Preparation: refers to various operations that occur during the period before a disaster strikes.
- ✓ Response: refers to the various operations that are instantly implemented after a disaster occurs.
- ✓ Reconstruction: refers to different operations in the aftermath of a disaster. It involves rehabilitation, and this phase aims to address the problem.

As mentioned above, HSC involved many stages and players that each player in any stage encounters various risks. Hence, the efficiency of the chain depends on the proper management of these risks.

Identification of areas and activities that could damage the part of a chain and face the people to danger, is a crucial action. Hence, the importance of risk identification and risk management techniques becomes apparent. Risk management aims to identify and evaluate risky situations and presents strategies to reduce risks [14].

Crisis management is the combination of planning and performance of government, NGOs, and social organization as integrated and coordinated to prevent and mitigation of effects, preparedness, response, and reconstruction.

C. Risk Management

Risk is defined as uncertainty based on a well-grounded probability. Also, Risk is defined as: Risk = (the probability that events will occur) * (the outcomes if it does occur) [15].

Risk management focused on recognition, analysis and economical control of risks, or probability of risks which can threat properties and economical incomes of companies. Heeringen (2010) defines risk management as a general management function that seeks to assess and address risks in the context of the overall aims of the organization [3]. The compliance with appropriate procedures and corporate governance policies can help to reduce or avoid crisis situations risk management entails identifying operational risks and developing mitigation procedures for maintaining operational performance [15].

An initial definition of SC risk is encompassed by Zsidisin and Ritchie [15] as "the potential occurrence of an incident or failure to seize opportunities with inbound supply in which its outcomes result in a financial loss for the firm."

In today's competitive global world, many risks threat SC organizations, and many researchers have addressed these issues. Specific SC risks considered by various studies are given in Table I.

TABLE I
SUMMARY ON TYPES OF SC RISK

Category	Risk	A	B	C	D	E
	External					
Nature	Natural disaster: flood, earthquake	*	*			*
	Plant fire					
	Diseases, epidemics		*			*
Political system	War, terrorism	*				*
	Labor disputes	*	*			*
	Customs and regulations	*	*	*		*
Competitor and market	Price fluctuation			*		
	Economic downturn		*			
	Exchange rate risk	*				
	Consumer demand volatility		*	*	*	
	Customer payment	*				
	New technology		*	*		
	Changes in competitive advantage			*		
	Obsolescence	*				
	Substitution alternatives					
	Internal					
Available capacity	Capacity cost	*	*			
	Financial capacity/insurance		*	*		
	Ability to increase production	*		*		
	Structural capacity		*	*		
	Supplier bankruptcy					
Internal operation	Forecast inaccuracy	*	*			
	Safety (worker accidents)		*			*
	Bullwhip effect	*		*		
	Agility/flexibility		*	*		
	Holding cost/order fulfillment tradeoff	*				
	On-time delivery		*			
	Quality		*			
Information system	IS breakdown	*				
	Distorted information					*
	Integration	*				*
	Viruses/bugs/hackers		*			*

Notes: A – [16]; B – [17]; C – [18]; D – [19]; E – [20].

SCRM is a field of escalating importance and its purpose is developing approaches to the identification, assessment, analysis and treatment of areas of vulnerability and risk in SC [21]. Performing SCRM is difficult because individual risks are often interconnected. As a result, actions that mitigate one risk can end up exacerbating another [16].

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III. Research Methodologies

A. The HSC Risks

This section discusses the HSC risks that may occur in disasters. National Governors Association (1979) suggested a four-stage process model to disaster relief [22]. Authors believe that many risks exist in each phase of HSC. Hence, in this study, the interview was used to identify the risk factors of HSC. After an interview with the decision team, the main risk factors were extracted, that were shown in Table II. This research was done in Tehran Red Crescent society. The decision team includes four top managers of Tehran RCSs.

TABLE II
List of HSC Risks and Their Short Descriptions

Risk factors	Short description
integrated management system (R1)	Poor management for collecting aids and coordinating the involved organization.
cooperation and coordination (R2)	Poor coordination and cooperation between organizations involved in disaster relief.
Foreign rescuers management (R3)	Leads to facilitating relief operations and assistance to local relief workers.
Poor supervision and tracking reconstructions (R4)	Poor track reconstruction, enhance people's problems.
Cost Management Systems (R5)	Cost management, assigns more facilities to more people and reduce irrelevant costs.
little awareness (R6)	Poor People awareness of the responsibilities of organizations involved.
The loss of Rescuers during the disaster (R7)	Loss of members of the rescue team with those skills can create delays in program implementation, as well as effect implementation costs.
On time presence in disaster zone (R8)	Leads to saving more people and reducing the impact of disasters.
Delays in the delivery and distribution aids (R9)	Increases the problems resulted from disaster.
Impact of boycott (R10)	Boycott of specialized equipment (helicopters, ambulances…), medicine and....
Security (R11)	Terror, theft, murder… Are the problems that may occur after a disaster.
International regulations (R12)	Regulations can interrupt the arrival of humanitarian aids.
Weak advertising (R13)	Advertising to raise awareness in the face of disaster.
disability to meet the needs (R14)	Not satisfy the basic needs of people such as food, tents, medicine, water and....
Poor education (R15)	Shortage of trained people in society and Inadequate rescuers training.
psychological support for injured (R16)	Psychological support, mitigate the survivor's problems.
Insufficient accurate information from the affected areas (R17)	Inadequate demographic information of the area makes it difficult to forecast and fulfill demand.
Shortage of specialized tools (R18)	Reduce the efficiency and effectiveness of rescue operations.
Lack of GPS system (R19)	GPS system provides identifying all points of the affected area for rescuers.
Concentrate resources in one area (R20)	Accidents in this area Leads to loss of resources and delays in sending goods to the Farther regions.
Block the communication paths (R21)	Caused a delay in the delivery of aids and relief operations.
Culture contexts (R22)	Increase the awareness and trained people, accelerate relief operations and more participate of individuals.

B. The BWM

BWM is a comparison-oriented MCDM method that compares the best criterion to the other criteria and all the other criteria to the worst criterion. The goal is to find the optimal weights and consistency ratio through a simple linear optimization model constructed by the comparison system [23].

Below is a description of the steps of BWM to calculate the weight of the criteria [24], [25]:

1) Determine the set of decision criteria $\{c_1, c_2, \ldots, c_n\}$ by decision-makers.
2) Determine the best and the worst criteria to be used for the decision environment: In this step, decision-makers choose the best and the worst criteria among the set of criteria identified in Step 1 from their perspective. The best criteria represent the most important criteria and the worst criteria are the least important criteria for the decision.
3) Determine the preference of the best criteria over all the other criteria: A number between 1 and 9 (1: equally important, 9: extremely more important) is used to indicate this value. The resulting Best-to-Others vector would be as $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$. Where $a_{B\mathrm{j}}$ indicates the preference of criteria B (best criteria) over criteria j and $a_{BB} = 1$.
4) Determine the preference of each of the other criteria over the worst criteria: A number between 1 and 9 is assigned to this case as well. The Others-to-Worst vector would be as $A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})^T$. Where, $a_{\mathrm{j}W}$ indicates the preference of the criteria j over the worst criteria W and $a_{\mathrm{WW}} = 1$.
5) Find the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$: Solving the problem (1) will result in the optimal weights for the criteria. To determine the optimal weights of the criteria, the maximum absolute differences $\{|w_B - a_{Bj} w_j|, |w_j - a_{jw} w_w|\}$ for all j should be minimized.

This model can be solved by transferring it to the linear programming (2) [26]:

$$\min \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\}$$
$$\text{s.t.} \quad \sum_j w_j = 1 \quad w_j \geq 0, \text{ for all } j \tag{1}$$

$$\min \xi \tag{2}$$

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s.t.

$$|w_B - a_{Bj}w_j| \leq \xi, \text{for all } j$$
$$|w_j - a_{jw}w_w| \leq \xi, \text{for all } j$$
$$\sum_j w_j = 1$$
$$w_j \geq 0, \text{for all } j$$

By solving this problem, the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$ and the optimal value of ξ^* are obtained. ξ^* Is defined as the consistency ratio of the comparison system. It means that the closer ξ^* is to zero the more consistent the comparison system is provided by the decision makers. (3) is used to check the consistency of the comparisons [27]:

$$Consistency\ Ratio = \frac{\xi^*}{Consistency\ Index} \tag{3}$$

The consistency index can be retrieved from Table III. The lower the consistency ratio, the higher the reliability of the comparisons.

TABLE III
CONSISTENCY INDEX TABLE

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

The flowchart of the proposed MCDM model is shown in Fig. 1.

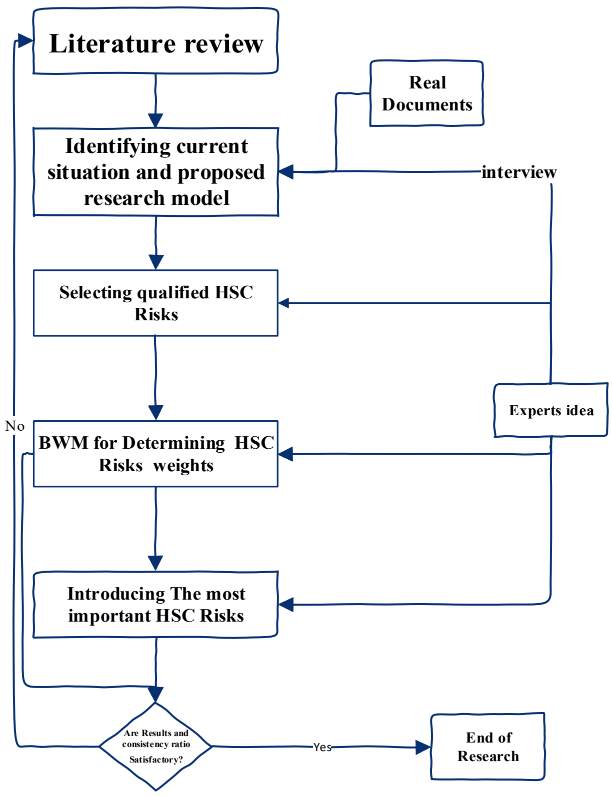

Fig. 1 Flowchart of the proposed MCDM model

IV. RESULT

At this step, BWM which was explained in sub section III-B is utilized to obtain importance weights of HSC Risks.

1. Determination of the Criteria Set

The criteria set is determined on the basis of the extensive literature review and interview with research experts as shown in Table II.

2. Determination of the Best and the Worst Criterion

The second step in the BWM is the determination of the best and the worst criterion. The best criterion is the one selected by each respondent as the most important HSC risks, while the worst criterion is the one which is the least important HSC risks based on the opinion of each expert. Experts of this research selected culture contexts (R22) as best criterion and international regulations (R12) as worst criterion, respectively.

3. Determination of the Preference of the Best Criterion over all the Others

This step consists of identifying the preferences of the best criterion from over all the other criteria. These data are gained by using BWM special questionnaire. The experts are asked to compare their selected best criterion with each of the other criteria and state their preference by using a value between 1 and 9. A score of 1 implies an equal importance over the other criteria. A score of 9 implies that the most important criterion is extremely more preferred with respect to the other criteria. Then, by calculating arithmetic mean of the four expert's questionnaires, aggregated Best-to-Others (BO) vector is constructed, which is illustrated in Table IV.

4. Determination of the Preference of all Criteria over the Worst Criterion

This step is similar to the previous step, but in this step, the experts are asked to state their preferences of all other criteria over the least important criterion. Similarly to the previous step, a value between 1 and 9 is used. Then, by calculating Arithmetic mean of 4 expert's questionnaires, aggregated

Others-to-Worst (OW) vector is constructed, which is illustrated in Table V.

5. Determination of the HSC Risks Weights

The weights of HSC Risks are calculated with a linear model (2) of BWM. By solving this linear model, optimized values of HSC Risks weights and ξ^* can be obtained. These results are shown in Table VI.

As can be seen from these results, in this case, 'culture contexts (R22)', 'little awareness (R6)' and 'poor education (R15)' are the most important HSC risks and, 'international regulations (R12)', 'foreign rescuers management (R3)' and 'the loss of rescuers during the disaster (R7)' are the least important HSC risks, respectively. As shown in Table VI, the comparisons show a very high consistency as the value of consistency ratio of criteria is close to zero (the consistency ratio for criteria comparisons is 0.0089).

TABLE IV
CONSISTENCY INDEX TABLE

Best criterion	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
R22	3.9	3.3	8.6	4.1	4.7	2.2	8.2	6.9	7.1	5.9	4.3	8.8	6.2	5.4	2.8	7.2	6.3	5.1	6.6	7.6	7.9	1

TABLE V
CRITERIA OW VECTOR

Worst criterion	R12
R1	7.5
R2	7.8
R3	2.1
R4	7.1
R5	6.6
R6	8.5
R7	2.8
R8	4.3
R9	4.1
R10	5.4
R11	6.9
R12	1
R13	5.2
R14	5.9
R15	8.1
R16	3.9
R17	4.8
R18	6.2
R19	4.6
R20	3.3
R21	3.1
R22	8.8

TABLE VI
HSC RISKS WEIGHTS

Criteria	Weight	Rank
R1	0.05290143	5
R2	0.06251987	4
R3	0.02399018	21
R4	0.05032087	6
R5	0.04389693	8
R6	0.09377980	2
R7	0.02516043	20
R8	0.02990081	15
R9	0.02905853	16
R10	0.03496874	11
R11	0.04798036	7
R12	0.01311422	22
R13	0.03327670	12
R14	0.03820659	10
R15	0.07368413	3
R16	0.02865494	17
R17	0.03274850	13
R18	0.04045403	9
R19	0.03125993	14
R20	0.02714678	18
R21	0.02611589	19
R22	0.1608603	1
ξ^*	0.04545522	
$\boldsymbol{Consistency\ Ratio}$	0.0089514	

V. DISCUSSION AND CONCLUSION

Today, preparedness and essential encountering with disasters are considered urgent in Iran and other countries around the world. This study was conducted for the analysis of HSCM risk in RSCs of Tehran as a good sample of the HSC of Iran.

A HSC is a system that is formed by different components from upstream to downstream, and the whole chain is an "organic" system that requires seamless integration.

In this research, first, specific SC risks by various studies are verified, then the factors of HSC risk management are identified. Finally, with using BWM method, the factors were ranked.

Identification and ranking risk management factors in HSC helped to reduce the risks step by step. Reducing the probability of HSC risk is essential action for improving the efficiency of relief operations in industries.

According to BWM results, the cultural context was known as the important risk of the HSC. Hence, acculturalization and improvement of the level of people culture is one of the requirements that should be considered in the context of disaster relief. Lack of cooperation and coordination among involved actor has a high rank. This inter-organizational risk is associated with all four phases of disaster relief and is the most frequently cited in the literature. The involved organizations in relief operations should have effective cooperation with relief aid suppliers to minimize the waste of time and facilitate fast delivery of aids. Coordination between the involved actors is further hampered when they are not familiar with capacities, procedures, and roles of one another. In order to address this challenge, the experts made the following recommendations. First, it is important to establish an organization or department as a command unit for synthesizing and coordinating the activities of all parties involved in humanitarian operations. Second, an interactive planning approach to relief and rescue operations should be pursued through holding regular meetings between different actors. Third, the IRCS should form a strategic long-term alliance with suppliers to ensure the availability of enough relief aids at anytime and anywhere. Finally, the involved actors should seek the help and consultation of local people in the affected areas to coordinate the allocation of relief aids.

One respondent highlighted the poor education as according to BWM result, and this is 3rd rank. In order to address this risk, two of the respondents expressed a need to "develop in-country certifications, and HSCM-related academic programs at universities for HSC managers". Another expert mentioned the need to "empower humanitarian organizations and people, invest in education, provide aid workers with better tools and techniques, and support the development of learning technologies". In this research, we proposed a novel methodological approach to understand HSCM risks. The

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integrated methodology in this research included the use of BWM approach. We believe that our methodological approach constitutes a relevant and powerful analysis tool in contexts. This approach is especially useful in exploratory studies where new theoretical insights are needed.

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