Computers & Industrial Engineering 101 (2016) 21–34

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

An outranking approach based on interval type-2 fuzzy sets to evaluate preparedness and response ability of non-governmental humanitarian relief organizations

Erkan Celik [a,*], Alev Taskin Gumus [b]

[a] Department of Industrial Engineering, Tunceli University, 62000 Tunceli, Turkey
[b] Department of Industrial Engineering, Yildiz Technical University, 34349 İstanbul, Turkey

ARTICLE INFO

Article history:
Received 19 March 2015
Received in revised form 6 June 2016
Accepted 24 August 2016
Available online 26 August 2016

Keywords:
Non-governmental humanitarian relief organizations
Humanitarian relief logistics
Type-2 fuzzy sets
AHP
PROMETHEE

ABSTRACT

After a disaster occurs, national and international non-governmental humanitarian relief organizations (NGOs), as well as the governmental humanitarian relief organizations (GOs), are involved in carrying out the humanitarian relief operations because of insufficiency in recourses such as lack of equipment and human resources. GOs and NGOs play a crucial role in preparedness and response to natural disasters, especially when available resources of them are not enough. The preparedness and response ability of GOs and NGOs aim to minimize the losses and number of affected people. Therefore, the preparedness and response ability of NGOs are becoming more important to support governmental relief activities. In this paper, a hybrid approach, that consists of interval type-2 fuzzy sets, AHP and PROMETHEE, is proposed to evaluate emergency preparedness and response ability performances of NGOs. The proposed hybrid approach is applied to NGOs in Turkey to evaluate their performances, and is conducted in three phases: (1) determination of critical success factors (CSFs) of humanitarian relief logistics management operations, (2) application of interval type-2 fuzzy AHP for obtaining importance weights of CSFs and (3) application of PROMETHEE based on interval type-2 fuzzy sets to evaluate preparedness and response abilities of NGOs.

1. Introduction

According to the records of The Centre for Research on the Epidemiology of Disasters (EM-DAT), 38 natural disasters have been registered between the years of 2004 and 2014, including 2011 Van (Ercis) earthquake, in Turkey. It is also estimated that 2,611 millions of dollars in economic damage and 1,031 casualties occurred, and, also, 242,696 of people affected from these events (EM-DAT, 2014). In these disasters, GOs and NGOs directly took an active role in relief activities (Disaster & Emergency Management Authority-AFAD, 2014). Because of the insufficient resources and funding of GOs, NGOs play a key and supporter role in relief activities. Hence, the efficient and effective preparedness and response ability of NGOs are crucial to obtain relief activities. The critical success factors (CSFs) have the greatest impact on humanitarian relief logistics (HRL) to sustain and improve relief activities of GOs and NGOs. CSFs are identified for managing disaster related public projects (Moe & Pathranarakul, 2006). A balanced scorecard model is also proposed for maximizing desired outcomes from natural disaster projects (Moe, Gehbauer, Senitz, & Mueller, 2007). Lu, Pettit, and Beresford (2006) consider six independent CSFs groups, which are strategic planning, inventory management, transport and capacity planning, information and human resource management, continuous improvement and collaboration, and technology utilization for emergency relief logistics. Pettit and Beresford (2009) identify and discuss CSFs to humanitarian aid sector based on commercial context. They also present the importance of determining the critical factors on success of HRL. Zhou, Weilai, and Ying (2011) indicate the most existing studies for emergency management trying to optimize certain procedures. They apply fuzzy DEMATEL approach for determining the CSFs which have great importance and impact on the emergency responses. According to their results, reasonable organizational structure and clear awareness of responsibilities are determined to have the highest impact on the whole system.

This paper evaluates the success of NGOs' operations in Turkey in HRL activities with respect to CSFs. Hence, a hybrid approach that consists of interval type-2 fuzzy sets (IT2FSs), Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is proposed to evaluate

* Corresponding author.
E-mail addresses: erkcelik@yildiz.edu.tr, erkancelik@tunceli.edu.tr (E. Celik), ataskin@yildiz.edu.tr (A. Taskin Gumus).

http://dx.doi.org/10.1016/j.cie.2016.08.020
0360-8352/

emergency preparedness and response ability performances of NGOs. IT2FSs are preferred in this study because it involves more uncertainties than type-1 fuzzy sets. It provides additional degrees of freedom to represent the uncertainty and the fuzziness of the real world (Celik, Bilisik, Erdogan, Gumus, & Baracli, 2013; Chen & Lee, 2010; Dereli & Altun, 2013; Dereli, Baykasoglu, Altun, Durmusoglu, & Türksen, 2011). The proposed hybrid approach is applied to NGOs in Turkey to evaluate their performances, and is conducted in three phases. In the first phase, CSFs of HRL are determined. The interval type-2 fuzzy AHP is applied to calculate the importance weights of each CSF, in the second stage. PROMETHEE based on IT2FSs is applied to evaluate preparedness and response ability of NGOs, in the last stage. The rest of this paper is organized as follows: Section 2 presents the type-2 fuzzy sets, interval type-2 fuzzy AHP and interval type-2 fuzzy PROMETHEE approaches used in the proposed approach to evaluate the NGOs. Then, the application of the proposed approach is presented in Section 3, to evaluate the NGOs based on CSFs. Finally, the conclusions are given in the last section.

2. The proposed outranking approach

In this section, first, the fundamentals of IT2FSs, steps of AHP based on IT2FSs, and steps of PROMETHEE based on IT2FSs are presented. Later, the proposed approach is explained in detail.

2.1. Interval type-2 fuzzy sets

IT2FSs are extensions of type-1 fuzzy sets which are proposed by Zadeh (1975). IT2FSs involve more flexibility (Mendel, John, & Liu, 2006) and more uncertainty (Celik et al., 2013; Chen & Lee, 2010; Erdoğan & Kaya, 2016) than type-1 fuzzy sets. Dereli et al. (2011) present a literature review on industrial applications of IT2FSs and systems. They emphasize that IT2FSs handle more uncertainty, and hence, produce more accurate and robust results. Celik et al. (2013) present an integrated TOPSIS and GRA method for evaluating customer satisfaction of public transportation in Istanbul. Chen (2014) proposes an extended PROMETHEE based on IT2FSs to address imprecise or uncertain information. Abdullah and Najib (2014) present a new type-2 fuzzy set of linguistic variables for AHP. Celik, Gumus, and Alegoz (2014) applied AHP for evaluating CSFs in HRL. In their paper, also, the importance weights of CSFs are obtained. Chen (2015) proposed a type-2 fuzzy TOPSIS using a likelihood-based comparison approach. A comprehensive review paper on MCDM based on IT2FSs has been recently presented by Celik, Gul, Aydin, Gumus, and Guneri (2015). Interested readers are directed to read this useful review paper.

The basic definition of IT2FSs is presented below (Akyuz & Celik, 2016; Celik et al., 2013; Celik, Gumus, et al., 2014; Celik, Aydin, & Gumus, 2014; Chen & Lee, 2010; Chen, 2014; Ghorabaee, 2016; Lee & Chen, 2008; Mendel et al., 2006):

An IT2FSs $\tilde{\tilde{A}}$ is presented by

$$\tilde{\tilde{A}}_i = \left(\tilde{A}_i^U, \tilde{A}_i^L\right) = \begin{pmatrix} \left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(\tilde{A}_i^U\right), H_2\left(\tilde{A}_i^U\right)\right), \\ \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(\tilde{A}_i^L\right), H_2\left(\tilde{A}_i^L\right)\right) \end{pmatrix}$$

which is shown in Fig. 1, where $\tilde{A}_i^U$ and $\tilde{A}_i^L$ are type-1 fuzzy sets, $a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U, a_{i1}^L, a_{i2}^L, a_{i3}^L$ and a_{i4}^L are the reference points of interval type-2 fuzzy $\tilde{\tilde{A}}_i$.$H_j\left(\tilde{A}_i^U\right)$ denotes the membership value of element $a_{i(j+1)}^U$ in the upper membership function $\tilde{A}_i^U; 1 \leqslant j \leqslant 2, H_j\left(\tilde{A}_i^L\right)$ denotes the membership value of the element $a_{i(j+1)}^L$ in the lower membership function

$$\tilde{A}_i^L; 1 \leqslant j \leqslant 2, H_j\left(\tilde{A}_i^L\right), H_1\left(\tilde{A}_i^U\right) \in [0,1], H_2\left(\tilde{A}_i^U\right) \in [0,1], H_1\left(\tilde{A}_i^L\right) \in [0,1], H_2\left(\tilde{A}_i^L\right) \in [0,1]$$

and $1 \leqslant i \leqslant n$.

2.2. AHP based on interval type-2 fuzzy sets

AHP, proposed by Saaty (1980), is a practical and useful decision making approach (Jalao, Wu, & Shunk, 2014), which has been studied extensively and applied to different specific areas in last 20 years (Ho, 2008; Ishizaka & Labib, 2011; Subramanian & Ramanathan, 2012). The initial fuzzy AHP is proposed by Van Laarhoven and Pedrycz (1983). Another extension of the fuzzy AHP with geometric mean is also proposed by Buckley (1985). Sari, Oztaysi, and Kahraman (2013) proposed an extension of AHP based on IT2FSs to select a warehouse location. Abdullah and Najib (2014) proposed a type-2 fuzzy AHP using a ranking method. Kahraman, Öztayşi, Uçal Sarı, and Turanoğlu (2014) also extended AHP based on IT2FSs by proposing a new ranking method for supplier selection problem. Gul, Celik, Gumus, and Guneri (2015) applied interval type-2 fuzzy AHP for determining important criteria in an emergency department. In this paper, Buckley's fuzzy AHP is preferred to determine importance weights of CSFs because of the easiness in applying it to fuzzy real case problems. The application of this extension is comparatively simpler and practical than other fuzzy AHP extensions (Gumus, 2009; Gumus, Yayla, Çelik, & Yildiz, 2013; Tadic, Gumus, Arsovski, Aleksic, & Stefanovic, 2013). The proposed AHP based on IT2FSs considers Buckley's (1985) five steps.

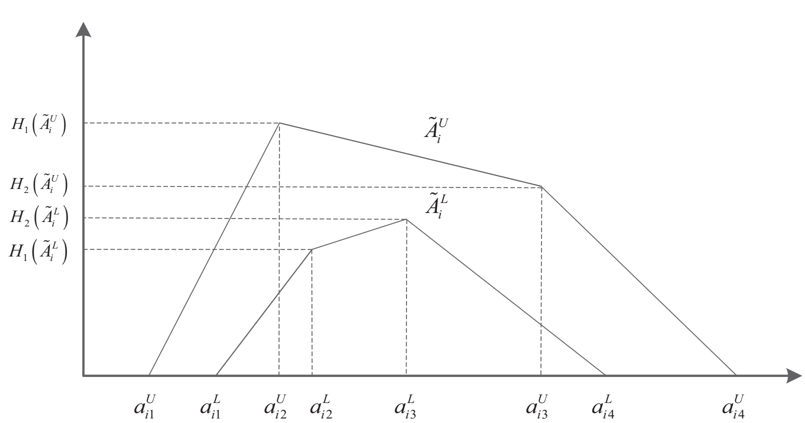

Fig. 1. The membership function of IT2FSs.