Information Sciences 303 (2015) 15–32

Contents lists available at ScienceDirect

Information Sciences

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

Relief supplies allocation and optimization by interval and fuzzy number approaches

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ARTICLE INFO

Article history:
Received 10 May 2014
Received in revised form 14 August 2014
Accepted 2 January 2015
Available online 14 January 2015

Keywords:
Large-scale disasters
Relief supplies allocation
Interval numbers
Fuzzy numbers
Decision-makers' preferences

ABSTRACT

In disaster responses, emergency decision-makers often consider multiple factors for allocating relief supplies to emergency distribution points (EDPs), and the information on these factors is not always precise. In this work, we formulate a preference-based index for comparing interval numbers, then combine the preference-based index with the α-cut idea to propose a new method for comparing triangular fuzzy numbers, and finally develop an approach for proportionately allocating limited relief supplies under situations with a mixture of crisp, interval and fuzzy numbers. Numerical simulations observe several findings: (i) The optimism degrees of emergency decision-makers would have an impact on relief supplies allocation if EDP situations have different uncertainty degrees; (ii) Compared with moderate decision-makers, optimistic (pessimistic) decision-makers often allocate more (less) relief supplies to EDP situations with lower uncertainty degrees; (iii) For mixed EDP situations, as the α-cut level increases, the impact of decision-makers' optimism degrees is gradually reduced.

1. Introduction

Large-scale disasters, such as earthquakes and infectious diseases, often push emergency decision-makers in disorientated situations. In response to these disasters, prompt relief supplies are key to reduce the loss of life [14]. It is a challenge to properly allocate scarce relief supplies to affected areas in different situations. At the response stage, the demands for relief supplies often have surging increases, and it is difficult or impossible to collect enough supplies under short preparation and pressing response time [3]. Thus, the available relief supplies are often proportionately allocated to different affected areas.

Recent researches have contributed numerous systematic decision making methods to the distribution of relief supplies in disaster responses. Fiedrich et al. [8] developed a dynamic optimization model for assigning limited resources to affected areas after strong earthquakes during the search-and-rescue period. Sheu [37] developed a dynamic relief-demand management model under imperfect information conditions in large-scale natural disasters. Liu and Zhao [19] formulated the distribution of emergency materials in anti-bioterrorism systems as a multiple traveling salesman problem. Zhang et al. [48]

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http://dx.doi.org/10.1016/j.ins.2015.01.002
0020-0255/

considered the secondary disasters to build an integer programming model with constraints of multiple resources. More related studies are reported in the review papers of Altat et al. [1], and Galindo and Batta [9].

Typically, the emergency logistics in the response stage consists of repeated decisions of collection, allocation and transportation of relief supplies [26]. In different decision phases, the situations such as available relief supplies, disaster levels and trapped populations are different [20,29], so every proportional allocation of relief supplies should be decided in accordance with the situations confronting the affected areas. However, the situation information available to the decision makers is mostly uncertain. The vital data are seldom crisp, usually containing interval and fuzzy numbers [36,44,20,30]. It would be valuable to the relief supplies allocators to have a more efficient way to handle such data. To the best of our knowledge, allocating limited relief supplies based on a set of crisp, interval and fuzzy numbers has not been addressed.

Motivated by the aforementioned discussion, we focus on the problem of allocating proportionally limited relief supplies under situations with crisp, interval and fuzzy numbers. In addition, we consider that different kinds of decision-makers have different preferences on interval and fuzzy numbers, which may further impact the allocation of relief supplies under uncertainty. Thus, our allocation method takes into account decision-makers' preferences.

The main contributions of this work are summarized below. (i) We formulate a preference-based index which could not only compare a mixture of crisp and interval numbers but also reflect the optimism degrees of decision-makers. (ii) Using the preference-based index and the α-cut idea, we propose a method for comparing fuzzy numbers. The method could reflect both the optimism degrees and uncertainty degrees of decision-makers' preferences on fuzzy numbers. (iii) Based on our contributions on comparing interval and fuzzy numbers, we develop an approach for proportionately allocating relief supplies under situations with a mixture of crisp, interval and fuzzy numbers. (iv) Numerical simulations observe several findings which could provide supports for the relief supplies allocation in real-world disaster responses.

The remainder of this paper is organized as follows. In Section 2, we give a brief account of current works on comparing interval and fuzzy numbers. In Section 3, we present our approach for allocating relief supplies under situations with a mixture of crisp, interval and fuzzy values. In Section 4, we use numerical simulations to verify the effectiveness and advantages of the developed approach. Conclusions are drawn in Section 5, with recommendations on future studies.

2. Related works

When proportionately allocating relief supplies under mixed situations, one key issue is how to compare crisp, interval and fuzzy numbers. Both interval and fuzzy algebras are old subjects, and various methods for comparing interval and fuzzy numbers have been proposed. However, extant approaches need to be improved in order to fully reflect decision-makers' preferences on uncertainty. In the following we review part of the extant studies (as Table 1 shows), and state the motivation of our contributions on comparing interval and fuzzy numbers.

Sunaga [38] early studied the interval algebra. Moore [23] enriched the interval algebra and applied it to automatic error analysis in digital computing. Ishibuchi and Tanaka [15] defined an order relation between two interval numbers, but their defined order relation does not discuss "how much higher" when one interval is known to be higher than another [33]. In order to measure the acceptability grade of one interval number being superior or inferior to another, Sengupta and Pal [33] defined an acceptability index. The acceptability index could compare the order relations of interval numbers, and measure "how much higher or smaller" of one interval number than another. Sengupta et al. [34] further applied this index to linear programming problems. However, Sengupta and Pal's index is not valid for comparing crisp numbers, so it cannot be used to

Table 1
Related studies on comparing interval and fuzzy numbers.

Papers	Contributions	Whether to measure "How much higher"	Whether to compare crisp and interval numbers	Whether to reflect degree of optimism
On comparing interval numbers				
Ishibuchi and Tanaka [15]	Defined an order relation	No	Yes	No
Sengupta and Pal [33]	Defined an acceptability index	Yes	No	No
Sengupta et al. [34]	Defined an acceptability index	Yes	No	No
Giove [10]	Proposed a modified index	Yes	Yes	No
Our work	Proposes a preference-based index	Yes	Yes	Yes
		Whether to compare crisp and fuzzy numbers	Whether to reflect degree of optimism	Whether to reflect degree of uncertainty
On comparing fuzzy numbers				
Chen [6]	Proposed the maximizing and minimizing set method	No	No	No
Chou et al. [7]	Improved the maximizing and minimizing set method	No	Yes	No
Wang and Luoh [41]	Initiated the centroid-based method	Yes	No	No
Liou and Wang [18]	Proposed the integral-based method	Yes	Yes	No
Our work	Proposes a new method	Yes	Yes	Yes