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Location selection of city logistics centers under sustainability

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ABSTRACT

City Logistics Centers (CLC) are an important part of the modern urban logistics system, and the selection of the location of a CLC has become a key problem in logistics and supply chain management. Integrating the economic, environmental, and social dimensions of sustainable development, this paper presents a new evaluation system for the location selection of a CLC from a sustainability perspective. A fuzzy multi-attribute group decision making (FMAGDM) technique based on a linguistic 2-tuple is used to evaluate potential alternative CLC locations. In this method, the linguistic evaluation values of all the evaluation criteria are transformed into linguistic 2-tuples. A new 2-tuple hybrid ordered weighted averaging (THOWA) operator is presented to aggregate the overall evaluation values of all experts into a collective evaluation value for each alternative, which is then used to rank and select alternative CLC locations. An application example is provided to validate the method developed and to highlight the implementation, practicality, and effectiveness by comparing with the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method.

Introduction

Since the start of this decade, more than 100 million people have migrated to cities globally (Lee, 2014). By 2050, the World Health Organisation estimates that at least 70% of the world's population will live in cities (Lee, 2014). Cities, being an accelerator for economic growth, will continue to grow and propel the much needed economic development for a country. Indeed, urban logistics has become an important part of a city's growth and development. An advanced and well developed city logistics system can hasten the rate of economic growth, reduce unnecessary transaction cost, enhance economic efficiency, improve investment climate, increase foreign direct investment, solve urban unemployment, and promote the development of the regional economy. However, studies also show that the last mile of the urban logistics system is the most expensive, inefficient and pollutive part of the supply chain (Gevaers et al., 2009). Thus, there is an imperative to improve urban logistics so that people can live, work and play in a high quality environment. Logistics infrastructure, notably the logistics centres servicing the logistics needs of a city, needs to be blended well with the rest of the supply chain.

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As a key logistics node, the City Logistics Center (CLC) is an important part of the modern urban logistics system, and has a pivotal position in the logistics system. A CLC is described as a logistics facility that is situated in relatively close proximity to the geographic area that it serves, be that a city center, an entire town or a specific site (e.g. shopping mall), from which consolidated deliveries are performed within that vicinity (Crainic et al., 2009). A range of other value-added logistics and retail services can also be provided at the CLC. The selection of the location of a CLC has become a key concern in logistics and supply chain management practice and design. The rationality and feasibility of the location selection and layout of the CLC affects the functioning, efficiency, and external costs for the city and her residents. For a start, a well considered CLC will reduce the logistics cost, improve the efficiency of transport flows, improve a citizen's living condition, sustain the city's economic vitality and can contribute to the harmonious development of the economy, environment and society. However, a poorly designed CLC can trigger a series of negative externalities and external costs, such as greater traffic congestion, increased emissions, road safety, and damaged urban image. Hence, a study on the selection of the location of a CLC from the perspective of the different stakeholders and their conflicting objectives has valuable theoretical significance and application merit.

From the literature, the CLC location selection problem can be classified as a special case of the facility location problem (FLP) (Owen and Daskin, 1998; Melo et al., 2009; Beresnev, 2013). It is a complex decision which involves the consideration of multiple factors including politics, economics, infrastructure, environment, competition, development strategy, product features, logistics cost, and customer service levels. The study of location theory formally began in 1909 when Weber first considered how to position a single warehouse so as to minimize the total distance between it and several customers (Owen and Daskin, 1998). Since the 1970s, the literature is replete with work on location theory. We name a few recent key works for completeness, for example, the hybrid multi-start heuristic (Resende and Werneck, 2006), second-order cone programming (Wagner et al., 2009), approximation algorithms (Huang and Li, 2008; Li, 2013), greedy heuristic and fix-and-optimize heuristic (Ghaderi and Jabalameli, 2013), Lagrangian relaxation heuristic (Nezhad et al., 2013), mixed integer linear programming model (Kratica et al., 2014), discrete variant of unconscious search (Ardjmand et al., 2014), multi-objective optimization model (Tang et al., 2013), and the weighted Dantzig–Wolfe decomposition and path-relinking combined method (Li et al., 2014), which have been presented for solving an uncapacitated facility location problem. Also, some algorithms and methods have been proposed for solving the capacitated facility location problem to optimality such as the mixed integer programming formulation (Melkote and Daskin, 2001; Aros-Vera et al., 2013; Rosa et al., 2014), branch-and-price algorithm (Klose and Görtz, 2007), Lagrangian heuristic algorithm (Wu et al., 2006; Elhedhli and Merrick, 2012), kernel search heuristic (Guastaroba and Speranza, 2014), Lagrangian Heuristic and Ant Colony System (Chen and Ting, 2008), Lagrangian relaxation algorithm (Yun et al., 2014), a fix-and-optimize heuristic based on the evolutionary fire-fly algorithm (Rahmaniani and Ghaderi, 2013), hybrid Firefly-Genetic Algorithm (Rahmani and MirHassani, 2014), swarm intelligence based on sample average approximation (Aydin and Murat, 2013), modified Clarke and Wright savings heuristic algorithm (Li et al., 2015), iterated tabu search heuristic (Ho, 2015), improved approximation algorithm (Aardal et al., 2015), two-stage robust models and algorithms (An et al., 2014), and the evolutionary multi-objective optimization approach (Rakas et al., 2004; Harris et al., 2014).

Much of the literature have studied the location selection problem under a certain and deterministic environment, that is, the parameters in the problem are fixed and known. In other words, many facility location problems were characterized as static and deterministic. These problems take constant, known quantities as inputs and derive a single solution to be implemented at a point in time. In practice, due to the complexity of the decision-making environment and their ambiguity, many parameters in the FLP are difficult to obtain with certainty. To deal with the decision of the FLP under an uncertain environment, fuzzy theory is developed and applied. For example, Chu (2002) proposed a fuzzy TOPSIS method under group decisions to solve the FLP. Likewise, Kahraman et al. (2003) proposed another solution approach of fuzzy multi-attribute group decision-making to solve the FLP. Wen and Iwamura (2008) have presented a new a-cost model under the Hurwicz criterion with fuzzy demands to solve the FLP under uncertainty and produced a hybrid intelligent algorithm to solve this model. Chou et al. (2008) present a new fuzzy multiple attribute decision-making approach, i.e., fuzzy simple additive weighting system, for solving the FLP by using objective/subjective attributes under group decision-making conditions. Önüt et al. (2010) proposed a combined fuzzy multi criteria decision making (MCDM) approach based on the fuzzy AHP and fuzzy TOPSIS techniques for selecting a suitable shopping center location. Li et al. (2011) used the axiomatic fuzzy set and TOPSIS method to select the CLC location. Wang and Watada (2012) studied a facility location model with fuzzy random parameters and its swarm intelligence approach, and established a Value-at-Risk (VaR) based fuzzy random facility location model (VaR-FRFLM) in which both the costs and demands are assumed to be fuzzy random variables. Recently, Ozgen and Gulsun (2014) combined possibilistic linear programming with fuzzy AHP to solve the multi-objective capacitated multi-FLP. Mokhtarian et al. (2014) proposed an Interval Valued Fuzzy-VlseKriterijumska Optimizacija I Kompromisno Resenje (IVF-VIKOR) method based on uncertainty risk reduction in the decision making process of facility location selection.

The traditional criteria applied to the FLP have predominantly focused on minimizing the economic cost or maximizing customer service level. With the emphasis on social responsibility and greater environmental awareness, this goal has now grown to include the selection of facility location with another criterion, that of sustainability, which means we must pay greater attention to address the challenging requirements of a sustainable facility location under the considerations of economic, environmental, and social dimensions. The considerations of both economic and environmental considerations in facility location selection decisions do exist (Melo et al., 2009; Harris et al., 2014), albeit scarce. This makes the consideration of economic, environmental, and social dimensions in facility location selection under uncertain environment more