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Development of decision support tool for optimizing urban emergency rescue facility locations to improve humanitarian logistics management

Ming Zhao[a,*], Xiang Liu[b]

[a] Research Center for Information Technology, China Waterborne Transport Research Institute, Ministry of Transport, Beijing 100088, China
[b] Beijing Nutrichem Company Limited, Beijing 102206, China

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ABSTRACT

Emergency rescue facility is an essential component of urban emergency logistics system, and selection of their locations is significant for urban public safety. Urban emergency rescue facility locations (UERFLs) problem is essentially a geospatial multi-objective optimization problem (Geospatial-MOP), which presents a challenge for both researchers and managers. In this study, a user-friendly decision support tool was designed and developed for facilitating the process of optimizing UERFLs in large-scale urban areas. We described the design, architecture and implementation of the tool and its core optimization component. Based on a hypothetical case study, we introduced its functionalities as well as the decision making workflow. The results provide evidences that the tool can successfully generate Pareto-optimal frontier and capture a pool of alternative solutions to the decision maker for trade-off. This work offers new insights on promoting future urban emergency logistics management with the use of GIS and emerging artificial intelligence technologies, and makes contributions in integrating multi-objective optimization algorithm with GIS for solving geospatial multi-objective optimization problem.

1. Introduction

China is undergoing rapid urbanization, and its urban population ratio has increased from 17.6% in 1978 to 54.8% in 2014 (Pan and Wei, 2015). “Accelerating urbanization” has been set as a national policy for years to come in China, and it is predicted that the urban population ratio of China will increase to about 70% by 2030 (13th Five-Year Plan, 2015; Pan and Wei, 2015). As an important “engine” of economic growth, urbanization has brought prosperity to China during the last three decades (Xiang et al., 2011). Nevertheless, emerging urban public safety and health issues accompanying with rapid urbanization have not received essential attention they deserve (Xiang et al., 2011; Zhao and Liu 2016).

In recent years, natural disasters (earthquakes, floods, hurricanes) and man-made accidents (terrorist attacks, chemical leakages, fire and explosion) have occurred frequently in the urban areas of China. These major disaster accidents can cause vast damage to a large-scale urban area in a short time, leaving many casualties behind (Georgiadou et al., 2007; Jia et al., 2007a, 2007b; Rawls and Turnquist, 2010; Caunhye et al., 2012, 2015, 2016; Ai et al., 2016; Santos et al., 2016; Boonmee et al., 2017). When accident occurs, tremendous amounts of relief materials (shelters, food, water, medicine, etc.) should be distributed to the demand regions quickly by setting up a number of emergency rescue facilities (FEMA, 2008; Caunhye et al., 2012; Rennemo et al., 2014). Emergency rescue facilities are thus essential component of urban emergency logistics system, and their locations are crucial for ensuring emergency rescue efficiency (FEMA, 2008; Lee et al., 2009; Horner and Downs, 2010; Maliszewski and Horner, 2010; Caunhye et al., 2012; Maliszewski et al., 2012; Zhao and Chen, 2015). In this context, developing strategies for optimizing urban emergency rescue facilities locations (UERFLs) is significant for disaster mitigation and public safety protection (Zhao and Chen, 2015).

Disaster accidents are extremely large-scale events, with the special characteristic of low frequency and sudden tremendous demand for supplies, distinguished from other regular emergency events (e.g., fire stations, medical centers) (Jia et al., 2007a). Moreover, in large-scale urban emergency logistics, the role of emergency rescue facilities is usually not only for relief distribution, but also for casualty transportation at the same time (Caunhye et al., 2012). These imply that the optimization model built for evaluating optimum UERFLs should be more comprehensive than regular emergency services (Zhao et al., 2017). In fact, large-scale UERFLs problem is not solely a general optimization problem, but a multi-objective optimization problem (MOP) (Jia et al., 2007a, 2007b; Huang et al., 2010; Caunhye et al., 2012; Zhao and Chen, 2015; Zhao et al., 2017).

The essential of UERFLs problem is geospatial calculation issue,

* Corresponding author.
E-mail address: nkwindancer@gmail.com (M. Zhao).

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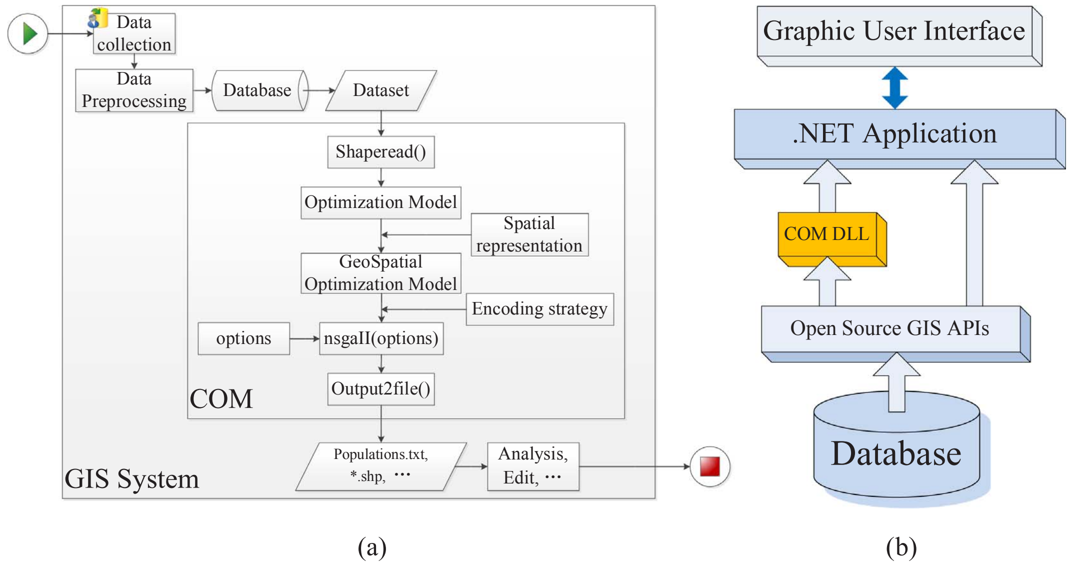

Fig. 1. (a) Conceptual design model and (b) system architecture of UERFLsOptimizer.

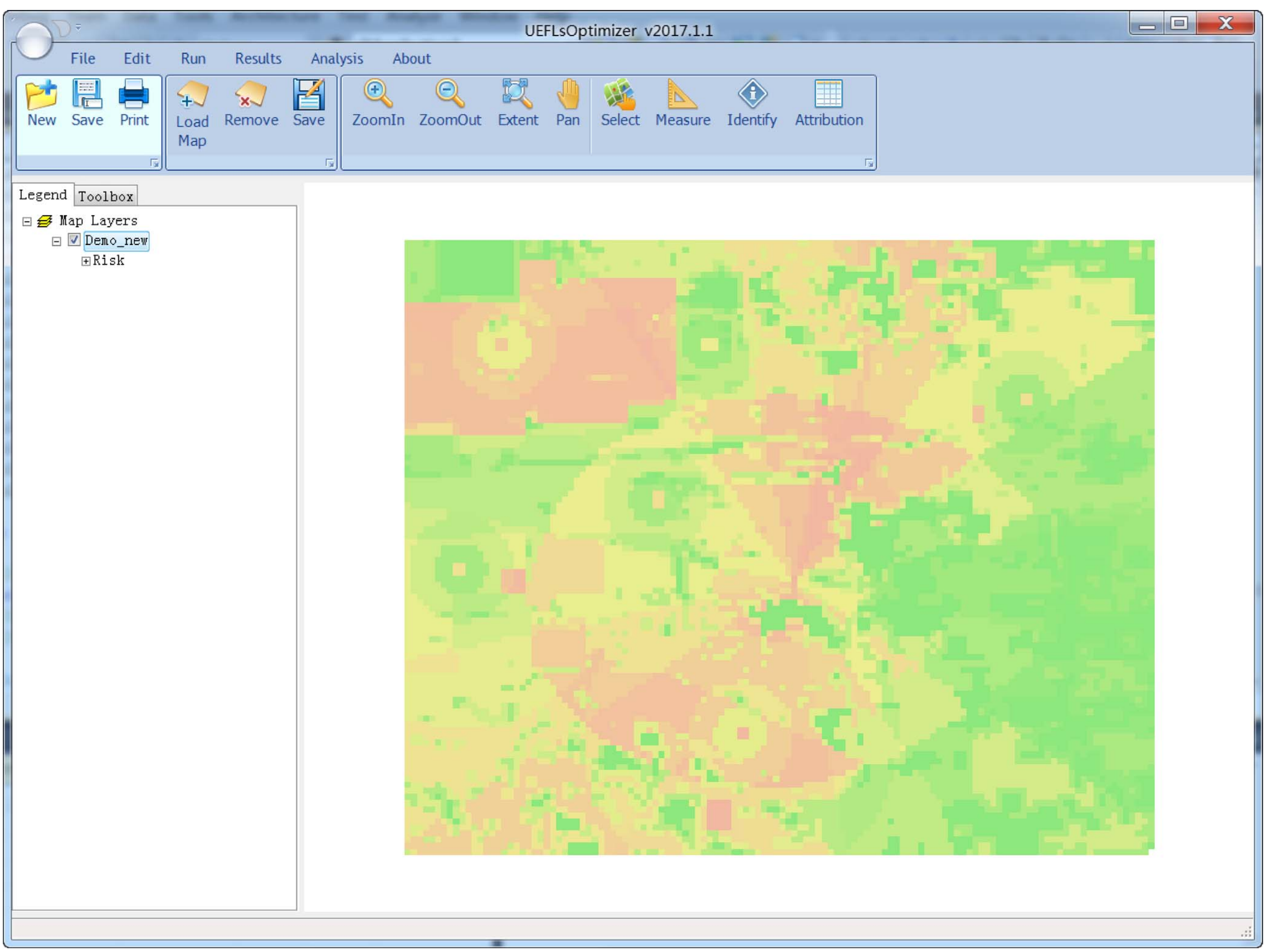

Fig. 2. Main graphical user interfaces (GUIs) of UERFLsOptimizer.

implying that its optimization process is computationally intensive (Zhao et al., 2017). In large-scale UERFLs optimization problem, it inevitably refers to the spatial pattern and natural geographical condition of urban system, implying that large-scale UERFLs optimization problem is not a general MOP, but a Geospatial-MOP (Zhao and Chen, 2015). Geospatial-MOP is recognized as a typical NP-hard problem, which presents another challenge for model solution (Zhao and Chen, 2015; Zhao et al., 2017). Especially in the Big Data age, the volume, the updating velocity, and the variety of geospatial data (Geo-Data) are too big, too fast and too diverse to process (Gao et al., 2017). With the