Transportation Research Part E 101 (2017) 30–58

Contents lists available at ScienceDirect

Transportation Research Part E

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

Site selection and vehicle routing for post-disaster rapid needs assessment

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ARTICLE INFO

Article history:
Received 6 May 2016
Received in revised form 9 December 2016
Accepted 14 January 2017

Keywords:
Humanitarian needs assessment
Coverage
Purposive sampling
Team orienteering
Tabu search

ABSTRACT

In the immediate aftermath of a disaster, relief agencies perform rapid needs assessment to investigate the effects of the disaster on the affected communities. Since assessments must be performed quickly, visiting all of the sites in the affected region may not be possible. Therefore, assessment teams must decide which sites to select and visit during the assessment horizon. In this paper, we address site selection and routing decisions of the rapid needs assessment teams which aim to evaluate the post-disaster conditions of different community groups, each carrying a distinct characteristic. We define the Selective Assessment Routing Problem (SARP) that constructs an assessment plan to cover different characteristics in a balanced way. The SARP is formulated as a variant of the team orienteering problem with a coverage objective. We develop an efficient tabu search heuristic, which produces high-quality solutions for the SARP. We illustrate our approach with a case study, which is based on real-world data from the 2011 Van earthquake in Turkey.

1. Introduction

Once a disaster occurs, humanitarian agencies first carry out rapid assessment of the affected region. The objective of the rapid assessment stage is to perform a broad evaluation of the disaster impact and population needs (Arii, 2013). The rapid assessment process may start as early as a few hours after the disaster occurrence, and is typically completed within three days (Arii, 2013). Assessments are conducted by experts, who are familiar with the local context and have specialties such as nutrition, shelter, etc. (ACAPS, 2011). For example, the Field Assessment Coordination Teams (FACT) of the International Federation of Red Cross and Red Crescent Societies (IFRC) is composed of disaster managers who can be deployed anywhere in the world within 12–24 h (IFRC, 2015). Also, the global rapid response team of the World Vision makes assessments within 24–72 h of the disaster (World Vision, 2016). A rapid needs assessment process involves "*making observations to feel the situation through sounds, smells and visual impressions*" and "*conducting interviews by key informants who have prior knowledge of the affected community*" (IFRC, 2008). The findings of the rapid needs assessment stage help agencies to determine the scale and the scope of the required response, prepare funding appeals, and prioritize needs (IFRC, 2008). Therefore, developing effective rapid assessment plans is crucial for achieving successful disaster response. Starting to deliver assistance without a rapid assessment may lead to significant gaps or overlaps in relief efforts and wastes of precious resources (Arii, 2013).

Since rapid needs assessment stage must be completed quickly, assessment teams do not make observations at all of the affected sites; therefore, sites to be visited are sampled. The general aim of sampling in the rapid needs assessment stage is to choose a limited number of sites that will allow the assessment teams to observe and compare the post-disaster conditions

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http://dx.doi.org/10.1016/j.tre.2017.01.002
1366-5545/

of different community groups (e.g., farmers versus pastoralists). In practice, two sampling methods are mainly used to select sites (IFRC, 2008). In random sampling, sites to be visited are selected randomly, which may be reasonable if all community groups in the region are affected by the disaster in a similar way. However, random sampling may not produce accurate findings if the post-disaster conditions change throughout the affected region. Therefore, relief organizations usually implement a *purposive sampling* strategy, in which only sites that carry certain characteristics are visited (ACAPS, 2011). The steps of developing an assessment plan by using purposive sampling are as follows (ACAPS, 2011):

i. *Specify the critical characteristics*. The critical characteristics that define the target community groups are identified. These characteristics may be related to geographical (e.g., topography, altitude), demographical (e.g., age, gender), socio-economical (e.g., economic activity, literacy) and socio-cultural (e.g., ethnicity, language) aspects (IASC, 2012; ACAPS, 2011). In general, it is important to avoid considering too many characteristics and to focus on the most critical ones (ACAPS, 2011).
ii. *Site selection*. A large number of sites may not be visited within the assessment period by using the available resources (such as staff and vehicles). While selecting sites, agencies mainly consider: (i) *sample richness* (i.e., observing each community group at least once is important), (ii) *collecting adequate information* (i.e., observing a community group at several sites is desirable to understand the situation better), and *efficiency* (e.g., visiting a site that involves multiple community groups may be beneficial).
iii. *Logistical planning*. Selected sites are assigned to teams and the order of visits to the sites for each team is determined. If feasible assessment routes cannot be constructed, the steps above are repeated to reduce the number of critical characteristics and/or the number of selected sites.

The above trial-and-error process may be time-consuming and may not guarantee obtaining an effective assessment plan. In this study, we focus on developing a systematic method that can be used by relief agencies to determine site selection and vehicle routing decisions simultaneously while implementing purposive sampling. We assume that the critical characteristics that define community groups are specified in advance. Each community group is identified by a single characteristic, and each site may involve different community groups. Then, given the set of critical characteristics carried by each site, we define the Selective Assessment Routing Problem (SARP) that determines: (i) the sites to visit and (ii) the vehicle routes (i.e., the assignment of the selected sites to the assessment teams and the order of visits to the sites by each team), while ensuring sufficient coverage of the critical characteristics within the assessment period.

Defining and measuring coverage is not straightforward in this context. In this study, we take a first step and define a coverage objective to address the site selection criteria considered in practice. Specifically, in SARP, we define a coverage objective, which *maximizes the minimum coverage ratio across the critical characteristics*; the coverage ratio of a characteristic is calculated by dividing the number of times that the characteristic is covered in the assessment plan by the total number of sites in the network carrying that characteristic. This objective aims to cover each critical characteristic at least once in order to ensure sample richness; and if the duration of the assessment period allows one to make further observations, additional sites are selected so that the critical characteristics are covered in a balanced way, which facilitates collecting adequate information while ensuring diversity. The SARP involves route duration constraints, which define the assessment deadline and make visiting sites that involve multiple characteristics desirable.

The SARP shows similarities with the Team Orienteering Problem (TOP) (Chao et al., 1996a) as both problems address site selection and vehicle routing decisions and focus on two objectives, which are maximizing the benefits collected from the visited nodes and constructing efficient routes. Similar to the TOP, we model the SARP by maximizing a benefit measure in the objective function and incorporating route efficiency concerns through the constraints. There is a rich literature that focuses on solution algorithms for the TOP. However, the existing algorithms for the TOP cannot be directly implemented to solve the SARP due to the significant differences between these problems in terms of the benefits collected from site visits and the objective functions. In TOP, a profit is associated with each site, and the objective is to maximize the total profit collected from the selected sites. In SARP, the benefit from visiting a site cannot be measured in terms of a single measure (such as profit) as the sites may carry multiple characteristics. Due to the *maxmin* coverage objective of the SARP, the potential value of a site cannot be evaluated in isolation from the other sites that could be included in the assessment plan. In this paper, we present a tabu search heuristic that can solve the SARP effectively. We present a computational study to evaluate the performance of the algorithm and illustrate our approach on a case study, developed by processing real-world data from the 2011 Van (Turkey) earthquake.

In Section 2, we review the relevant literature. In Section 3, we define the SARP and present the mathematical model. We explain our solution algorithm in Section 4 and present computational results in Section 5. We present a case study in Section 6. Finally, we conclude and discuss future work in Section 7.

2. Literature review

In Section 2.1, we review the relevant studies related to the humanitarian needs assessment processes. In Section 2.2, we review the related routing literature.