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Integrating uncertain user-generated demand data when locating facilities for disaster response commodity distribution

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ABSTRACT

This paper presents a new facility location problem variant with application in disaster relief. The problem is unique in that both verified data and unverified user-generated data are available for consideration during decision making. The problem is motivated by the recent need of integrating unverified social data (e.g., Twitter posts) with data from more traditional sources, such as on-the-ground assessments and aerial flyovers, to make optimal decisions during disaster relief. Integrating social data can enable identifying larger numbers of needs in shorter amounts of time, but because the information is unverified, some of it may be inaccurate. This paper seeks to provide a “proof of concept” illustrating how the unverified social data may be exploited. To do so, a framework for incorporating uncertain user-generated data when locating Points of Distribution (PODs) for disaster relief is presented. Then, three decision strategies that differ in how the uncertain data is considered are defined. Finally, the framework and decision strategies are demonstrated via a small computational study to illustrate the benefits user-generated data may afford across a variety of disaster scenarios.

1. Introduction

Disasters are prevalent today and the rapid delivery of food, water and medical attention is critical in minimizing suffering for those impacted. Over 6900 disasters were reported during the ten year period from 2002 to 2011, causing over 1.2 million total deaths and affecting almost 2.7 billion people worldwide [26]. Mega-disasters resulting in massive death tolls occurred both in 2010 with the earthquake in Haiti and in 2011 with the earthquake and tsunami in Japan [9]. Disasters leave impacted populations in need of food, water, shelter, and medical attention, among other things. Major relief organizations such as the International Federation of Red Cross and Red Crescent Societies recognize the critical roles of logistics and the optimized use of scarce resources in saving lives in disasters [25]. The academic community is also aware of the importance of logistics in disaster operations. The authors of a 2011 survey paper on disaster relief routing state “much of successful and rapid relief relies on the logistics operations of supply delivery” [5].

The Federal Emergency Management Association (FEMA) describes three primary methods of issuing supplies after a disaster [1]. Using *mobile delivery*, vehicles deliver supplies directly to drop locations and points where needs have been identified. This method is useful in rural areas and where transportation infrastructure damage has occurred. Using *direct delivery*, supplies are delivered to a specific location such as a shelter or hospital. The types of supplies to be delivered and quantities of each are predetermined. Lastly, in the *Points of Distribution* (POD) method, commodities are delivered to centralized points (i.e., PODs) and impacted populations come to the PODs to pick them up. The available commodities typically include food and water and may also include ice, tarps and blankets [1]. To summarize, supplies are taken to the end users in the mobile and direct delivery methods, while the end users travel to the supplies when PODs are used. POD location decisions are the focus of this paper; specifically, those that must be made after a disaster occurs.

The timeline for POD operation depends on the scope of the disaster and is relatively short when compared with facilities in commercial settings. For example, the timeline outlined in one POD location paper suggests PODs will be established within four days post-disaster and operate until approximately one week post-disaster when there is a transition from response to recovery

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operations [23]. Within this context, required decisions in practice may include where and when to open PODs, when to close and/or relocate them, and what demand each will serve. The type of each POD may also need to be determined. The United States Army Corps of Engineers identifies three POD types, distinguishable primarily by their size and the number of persons they are intended to serve [1]. In this paper, we restrict our focus to only a subset of these POD-related decisions. Specifically, we study where to open uncapacitated PODs at a single point in time and what demand each will serve. By doing so, we are able to build preliminary insights regarding the incorporation of social data during the planning process.

In order to make good POD location decisions, information regarding the locations and needs of impacted groups is essential. Situational awareness refers to possessing an understanding of the situation at hand in order to inform better decisions. It is critical in planning logistics activities to support disaster response. Traditionally this information has become available as on the ground assessments – time consuming efforts – are completed. However, social media usage during emergencies is accelerating the pace at which information becomes available to emergency managers [36]. Surveys conducted by the American Red Cross in 2011 and 2012 concluded individuals within the U.S. are increasingly using social media to post information relevant to emergencies [42]. Social data that enhance situational awareness provide “tactical, actionable information that can aid people in making decisions” [40]. To inform location planning, a specific need and precise location should be communicated. Consider for example the Twitter post from Hurricane Sandy depicted in Fig. 1. It provides an address, states that a house is flooding and alerts the Fire Department of New York (FDNY) to the need. A response from FDNY demonstrates they were monitoring social data for this type of information. While the flooding example in this figure may not influence the placement of PODs, it is clear how social data does have the potential to inform such decisions. For example, if a large group of persons reports having no access to food and water, it may be reasonable to locate a POD near them. If emergency managers had no knowledge of these individuals, the individuals may need to travel farther to reach the nearest POD, or they may not be able to reach a POD at all.

The emergency management community is beginning to adapt to the new demand for social data integrated response activities. Three-quarters of emergency agencies participating in a 2012 survey conducted by CNA Analysis & Solutions and The National Emergency Management Association (NEMA) indicated their agencies use social media in some capacity [36]. The American Red Cross launched the first social-media monitoring platform dedicated to disaster relief in 2012 [43]. But despite movement in the emergency management community to adopt social data usage,

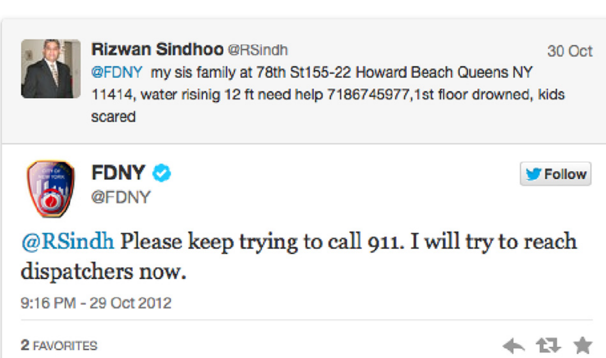

Fig. 1. Twitter post during Hurricane Sandy [35].

two primary barriers to seamlessly integrating social data with large-scale logistics response planning are evidenced. One such barrier is limited analytics infrastructure. Less than 12% of respondents to the CNA/NEMA survey indicate the social media capability at their agency includes data collection, aggregation, and analysis that are robust for large-scale events [36]. Concerns regarding the accuracy of social data constitute another barrier. Because the data is user-generated, it is initially not verified. A majority of respondents report trusting social media less than traditional sources, and indicate their agency would take action on social data only after verifying it [36]. It is true social data has the potential to be inaccurate. For example, a Twitter user in New York City intentionally spread alarming misinformation about Hurricane Sandy [11]. However, not all social data is inaccurate, and waiting to take action until it is verified contradicts one of its primary advantages – timeliness. Thus integrating unverified user-generated data in emergency planning yields a key tradeoff:

- serve more people in a shorter amount of time by allocating resources to needs that may otherwise be discovered later or not at all, or
- waste precious resources by allocating them to false needs.

In the context of POD location decisions, the specific tradeoff is between locating facilities such that more demand (both verified and unverified) can reach them in a short amount of time, versus potentially placing PODs farther away from the verified points than necessary. This paper presents a framework for evaluating this tradeoff.

The primary research question addressed in this paper is whether there is value in acting on user-generated data prior to its absolute verification in the context of POD location decisions. Given the limited analytics infrastructure in place at the majority of the agencies surveyed in 2012, the value of a social-data integrated approach must be demonstrated in order to spur technology development and diffusion throughout the disaster response enterprise. This paper makes a pivotal, albeit simple, first step towards answering this question. The rationale is as follows: each element of user-generated content (e.g., a Tweet, a youTube video) can be viewed as potentially admissible information in the planning process. The user-generated content specifies information about a demand point (e.g, the location and quantity of people in need of the supply or service). Based on this rationale, emergency managers need to choose a strategy regarding how the uncertain data will be incorporated into the planning process. For example, they may choose to ignore it completely, give it equal weight to the verified data, or pursue a compromise policy (where they, for instance, only consider a subset of the user-generated content). Through the models and a small computational study presented in this paper, the performance of such strategies across a range of disaster situations is evaluated. Specifically, the following three research questions are addressed: how do decision strategies that (i) ignore all unverified data, (ii) include all unverified data, and (iii) use scenario planning to account for unverified data perform across a range of disaster situations?

The contributions of this paper are as follows. A framework for incorporating uncertain user-generated data in disaster relief POD location decisions is presented. To the best of our knowledge, this is the first paper to simultaneously consider two classes of verified and unverified demand when placing facilities. Section 2 will describe how this is different from other literature on facility location under uncertainty and multi-commodity facility location. Second, the paper proposes three strategies that can be used by an emergency manager faced with a POD location decision for which both verified and unverified data are available. One of these reflects