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Modeling joint evacuation decisions in social networks: The case of Hurricane Sandy

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ABSTRACT

Coastal areas of the United States are vulnerable to substantial loss of lives and property damage from repeatedly occurring hurricanes and evacuation is the usual recourse to prevent loss of life when high storm surge threatens. The fundamental question in evacuation modeling is to explore the complex evacuation decision-making process leading to an individual's decision to evacuate or not during a hurricane threat. Recent studies suggest that the social network characteristics of individuals could potentially determine overall evacuation patterns. This study explores the joint evacuation decisions of individuals in personal networks by using ego-centric social network data obtained from Hurricane Sandy and by considering the nested structure of the ego-centric network data, i.e. close contacts (alters) as nested within an individual (ego). In this regard, the study develops a multinomial multilevel model of joint evacuation decisions at the dyadic (ego-alter tie) level utilizing a Hierarchical Generalized Linear Modeling (HGLM) approach. Model estimation results suggest factors that define a social tie (contact frequency, discussion topic and geographic proximity) significantly influence the evacuation decisions between individuals and their social partners. In addition, individuals' (both ego and alter) own socio-demographics such as age, marital status, previous evacuation experience, evacuation order, household's type, size, location and proximity to a water body also affect the decision to evacuate. These findings are useful to help emergency managers implement efficient evacuation strategies and to facilitate planning by policymakers by determining fractions of people evacuating or not for a major hurricane within the context of their social networks.

1. Introduction and motivation

Hurricane Sandy (October 2012) caused about 254 deaths in the US, Caribbean, and Bahamas with an estimated economic loss of $65 billion (USD) (Ehrhart et al., 2012). Seventy-two fatalities, including 41 drownings from storm surge, resulted from Sandy's wind and flood impact (Gladwin et al., 2013). Timely evacuation could have averted such storm surge deaths that were higher than all but two prior hurricanes (Katrina and Camille) in the past 60 years (National Hurricane Center, 2015). Most of Katrina's direct storm surge drowning deaths occurred in Mississippi included 200 fatalities that is nearly 0.00054% of the population. While Sandy's wind and waves heights were less than Katrina's category 4 hurricane winds and 30 foot waves in Mississippi, the death toll did not remotely approach the same proportion of the population affected by Katrina in Mississippi. Nonetheless, this death toll and what it could have been in a category four or five hurricane mandates further study of public evacuation decision-making for Sandy. Most of the New Jersey and New York residents who were interviewed for this study lived at locations where they probably should

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have evacuated but 74% did not finally evacuate (Fig. 2). By the time of the evacuation order many people were aware of the storm but apparently decided they would be safe staying in their homes. However, research done in the framework of Lindell's protective action decision model (Lindell et al., 2005; Lindell and Prater, 2007a, b) and household decision modeling (Gladwin et al., 2007) indicate that psychological and social factors are very important in translating hazard warning information into a collective decision. This research indicates that social networks within and outside of households are likely to play a major role in facilitating evacuation decision-making.

A likely mechanism for the effect of social networks in evacuation decision-making is social capital operating in social networks and social ties both traditionally defined, and as augmented by social media. According to one definition of social capital, individuals exchange resources such as information, ideas, support and others through relationships with other people, thus considering social capital as the extent to which an individual involves himself in different informal networks as well as formal civic organizations (Putnam, 1995, 2001). This conceptualizes social capital as the many different ways members of a given community interact with each other as an indication of that community's associational life and civic health, including participating in recreational activities, talking to neighbors, joining political parties or environmental organizations and so on. Similarly, Coleman defined social capital by its function that includes different entities with two common elements: an aspect of social structures and certain facilitating actions of actors within the structure (Coleman, 1988). The prospect of social capital in building more resilient communities has been explored recently (Aldrich, 2012) explaining how such communities may become proactive in absorbing sudden shocks specially during post-disasters. That study identified social capital as the single most contributing factor during post-disaster recovery and suggested individuals and neighborhoods with weaker ties faced more difficulties as a result of inaccurate interactions with organized and mobilized groups.

A more network-oriented perspective relevant to social capital is to consider the personal networks of individuals' i.e. ego-centric social networks (Borgatti and Halgin, 2011; Burt, 1984, 1985, 2000; Halgin and Borgatti, 2012). The General Social Survey (GSS), first conducted in 1972, measured core discussion networks among Americans (Burt, 1985; Marsden, 1987) and several studies have used these GSS discussion network measures (Brashears, 2011; Wellman, 1979). The particular questionnaire item involved from GSS has been widely used by researchers because of its parsimony, general nature, applicability to various contexts and ability to capture ego's core discussion networks without focus on specific network content (Bailey and Marsden, 1999; Burt, 1984; Carrasco et al., 2013; Kowald et al., 2010; Sadri et al., 2015a; van den Berg et al., 2009). In contrast, Granovettor gave more stress to the cohesive power of weak ties and suggested that occasional and informal ties have the ability to link different groups of individuals that could provide access to newer resources or support (Granovetter, 1973). As a result, conceptual debates on social capital cannot be resolved in an empirical vacuum (Grootaert et al., 2003).

Frequently occurring hurricanes in the coastal areas of United States require that different stakeholders, particularly emergency planners and officials, understand the overall evacuation process thoroughly and identify key determinants of evacuation behavior in reducing the amount of risk associated with vulnerable communities. The key requirement is to explore evacuation decision-making behavior (i.e. who evacuates and who does not) and the causal factors influencing this behavior. Within the overall amount of research conducted on the issue of evacuation, few studies do this. The central idea of this paper is to analyze joint evacuation decision-making behavior of individuals in a personal network setting using ego-centric social network data obtained from Hurricane Sandy and considering the nested structure of the data i.e. friends or close contacts (alters) being nested within an individual (ego). In this regard, this study develops a multinomial multilevel model of joint evacuation decision outcome at the dyadic (ego-alter tie) level using Hierarchical Generalized Linear Modeling (HGLM) approach to investigate the effects of relational or tie attributes in addition to individuals' own socio-demographic characteristics.

Social media served as an essential source of information sharing during Hurricane Sandy. Many residents lacking access to traditional sources of information (television for example), received information on smart-phones using social media (Kaufman et al., 2012). Social media communications in areas without power (Midtown Manhattan was the most common tweeting location) continued throughout and after the storm as the continuous distribution of tweets spread throughout the city (Floating Sheep, 2012). While social media pertains to virtual or online social connections, they can reflect real social ties that can influence individual evacuation decisions. Hasan and Ukkusuri found that warning information propagates faster within networks with greater inter-community connections using a simulation based approach (Hasan and Ukkusuri, 2011). Another earlier study presented a contagion model to explain how people first receive emergency warning information and then spread the information to others (Rogers and Sorensen, 1991). These network effects were stressed in the policy proposal of Gladwin et al. on necessary actions required by appropriate agencies and organizations to support social science research on the major issues in the hurricane forecast and warning system (Gladwin et al., 2007). Social network characteristics and warning information sources significantly influenced individual-level evacuation decision making during Hurricane Sandy (Sadri et al., 2016).

This study is organized as follows: the next section summarizes existing literature on hurricane evacuation decision-making; Section 3 describes the data and explains the personal network research design approach; Section 4 presents the methodology used to develop the model; Section 5 elaborates the model estimation results; and Section 6 concludes the study with a discussion of key findings.

2. Background and related work

Evacuation is a typical form of travel during extreme events and it is the usual recourse to prevent loss of life if high storm surge occurs. However, evacuees often show synchronized behavior in terms of when they depart and what route they take. (Wolshon, 2002). Several studies show important factors affecting evacuation decisions such as hurricane trajectory and warning system,