USDOT Region V Regional University Transportation Center Final Report

NEXTRANS Project No. 160PUY2.2

Effects of Heterogeneous Information Characteristics and Sources on Evacuation Behavior

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DISCLAIMER

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TECHNICAL SUMMARY

NEXTRANS Project No. 160PUY2.2 Final Report, April 30, 2017

Title

Effects of Heterogeneous Information Characteristics and Sources on Evacuation Behavior

Introduction

Mass evacuation is required when a nature (e.g. hurricane) or man-made (e.g. terrorist attack) disaster poses immediate or potential threat to the population in the affected areas, and the issuance of the evacuation notice is often crucial to ensure the success of the evacuation. One important element that directly affects the issuance of the evacuation notice is the lead-time in the predictability of a disaster's occurrence. Establishing and/or maintaining communication in no-notice evacuations are often found challenging due to the limited and impaired resources under the urgent situations. In addition to traditional communication platforms, social networking services (SNS), such as Facebook and Twitter, allow users to share information and establish communication with whom they share a connection in the urgent evacuation situations. The effectiveness of using SNS to assist no-notice evacuations depends on two important SNS-related behaviors of potential evacuees, including their levels of trust towards disaster and evacuation related information on SNS, and SNS usage during no-notice evacuations. The proposed study seeks to understand the differences in terms of levels of trust towards information of disaster occurrence notification and evacuation recommendation from different communication platforms (including SNS and traditional communication platforms) in no-notice evacuations. In addition, econometric models are created to understand the correlation between individual's socio-economic and behavioral characteristics and their behaviors related to SNS usage during no-notice evacuations.

Findings

To model evacuees' information disseminating behavior through SNS during a no-notice evacuation, individual characteristics and their SNS usage behavior are factorized in a mixed logit model. According to the estimation results, evacuation experience, SNS usage behavior, levels of trust towards information on SNS, and a few other individual characteristics show statistical significance in explaining people's information disseminating behavior through SNS (posting/reposting frequency) during a no-notice evacuation.

The various findings and insights can be used to assist EMAs in designing information dissemination strategies on SNS during a no-notice evacuation, including: (i) using SNS as complementary information dissemination platforms during a no-notice evacuation is feasible and even critical to ensure information of disaster occurrence notification and evacuation recommendation being delivered to a larger audience faster, especially in situations where traditional platforms are inefficient and/or insufficient; (ii) improving the reputation of EMAs to increase people's levels of trust towards the information from their accounts on SNS; (iii) reducing false alarms or perceived false alarms disseminated through both traditional platforms and SNS to improve people's levels of trust towards the information of disaster occurrence notification and evacuation recommendation; (iv) understanding why people perceive certain information of disaster occurrence notification and evacuation recommendation is important to spread is critical in motivating people to disseminate information during no-notice evacuations; (v) monitoring the information on SNS during no-notice evacuations to understand target audience's interest and adjusting information based their interest to increase information dissemination speed; (vi) identifying potential active users on SNS during no-notice evacuations based on their SNS posting/reposting frequency.

Recommendations

Given that the content of information of disaster occurrence notification and evacuation recommendation is same no matter which source that information is from in the survey, the results of the model cannot offer a picture of people's SNS-related behavior when they get inconsistent information from different sources during no-notice evacuations. Furthermore, the designed content of information includes disaster type (a radiation leak), affected area (the whole campus) and evacuation recommendation (leave the campus). Whether that content is enough to make people aware of their situations and take actions or not is not analyzed in this study. Further research intends to consider the inconsistent information from different sources, which may help EMAs to control rumor spreading on SNS during no-notice evacuations.

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CHAPTER 1. INTRODUCTION

1.1 Background and motivation

Mass evacuation is required when a nature (e.g. hurricane) or man-made (e.g. terrorist attack) disaster poses immediate or potential threat to the population in the affected areas, and the issuance of the evacuation notice is often crucial to ensure the success of the evacuation. One important element that directly affects the issuance of the evacuation notice is the lead-time in the predictability of a disaster's occurrence. On this basis, evacuations can be classified into two kinds: short-notice and no-notice evacuations (Hsu and Peeta, 2013). A short-notice evacuation (e.g. hurricanes and flooding) typically has a lead-time of one to three days, which allows emergency management agencies (EMAs) and potential evacuees to be prepared for the evacuation (Wolshon, 2002). By contrast, in a no-notice evacuation, potential evacuees are required to evacuate immediately after an unexpected disaster occurred (e.g. hazardous material leaks). In both types of evacuations, communication is crucial to possibly minimize losses and save lives (Prasanna and Huggins, 2016).

Establishing and/or maintaining communication in no-notice evacuations are often found challenging due to the limited and impaired resources under the urgent situations (Manoj and Baker, 2007). Traditional communication platforms, such as siren, people in uniform (e.g. law enforcement officers or firefighters), television, radio broadcasting, online communication (e.g. email), and telephone have been widely adopted by EMAs to communicate with disaster-affected people (especially those who are in need of urgent assistance) and other EMAs (Moore, 2008). Some of them can also be used by disaster-affected people to access and share information (Stephan, 2006). Despite that these

traditional platforms have been widely used to establish communication in many no-notice evacuations, in many of recent events, these platforms were found ineffective or unreliable due to infrastructure failure or insufficient communication capacity (Low et al., 2010). For example, in the September 11 attacks, overloaded radio channels along with overloaded cell phone systems in New York made the region exposed to additional risks (Seifert, 2002). In the 2008 Sichuan earthquake and 2011 Japan earthquake, infrastructure supporting the communication, such as electricity infrastructure, circuits for fixed lines and mobile base stations, was damaged, which made communication among EMAs and evacuees difficult (Kobayashi, 2014; Lin et al., 2015). In aforementioned situations, EMAs and disaster-affected people cannot rely on traditional communication platforms solely, which entails the needs to utilize other communication platforms, such as social networking services (SNS), to establish communication between EMAs and disaster-affected people (Bird et al., 2012).

Social networking services (SNS), such as Facebook and Twitter, are web-based services that allow users to share information and establish communication with whom they share a connection (Ellison, 2007). With the development of mobile and wireless technologies, more people start to use SNS, and it has already become one of the most common communication platforms. Recent studies show that 65% of adults in the United States (U.S.) now use SNS (Perrin, 2015), and 51.4% American adults use SNS daily in 2014 (Duggan et al., 2015). In the evacuation context, SNS allow people to access information and communicate during no-notice disasters when traditional communication platforms fail (Abbasi et al., 2010). For example, in the 2010 Chilean earthquake, traditional communication platforms were down for the first 48 hours after the earthquake due to infrastructure failure, while SNS communication was established less than 2 minutes after the earthquake (Mendoza et al., 2010). In addition, firsthand reporting by users on SNS can provide almost instantaneous information about the disaster, allowing EMAs, disaster-affected people and people outside the affected areas to learn and respond to the disaster (Lerman and Ghosh, 2010). These features make SNS potential communication platforms during no-notice evacuations, especially when traditional communication

platforms are insufficient or malfunctioning. It can also enable EMAs to collect disaster-related information faster and more efficiently.

Despite aforementioned advantages, how to use SNS as communication platforms during no-notice evacuations effectively is still a challenging (Manoj and Baker, 2007; Reddy et al., 2009). For example, in the 2016 Ohio State University (OSU) attack, OSU Emergency Management tweeted "Buckeye Alert: Active shooter on campus. Run Hide Fight. Watts Hall. 19th and College." to warn students to protect themselves. While the oversimplified sentence "Run Hide Fight" drew some criticism because that sentence, designed by Homeland Security, was not promoted in OSU, and not understood by Tweet users who received it (Knight and Saker, 2016). The effectiveness of using SNS to assist no-notice evacuations depends on two important SNS-related behaviors of potential evacuees, including their levels of trust towards disaster and evacuation related information on SNS, and SNS usage during no-notice evacuations. However, to authors' knowledge, none of the previous studies studied these behaviors.

1.2 Study objectives

The primary objective of this project is to investigate the different trust in information of disaster occurrence notification and evacuation recommendation from heterogenous communication platforms (including SNS and traditional communication platforms) in no-notice evacuations. Econometric models are created to understand the correlation between individual's socio-economic and behavioral characteristics and their behaviors related to SNS usage during no-notice evacuations. The specific research objectives in this project include:

(i) Review the current literature regarding evacuation behaviors including information seeking and evacuation decision-making in no-notice evacuations;

(ii) Explore the evacuation-related behavior along with intention to disseminate relevant information using SNS through a stated preference survey which also collect information about individuals' SNS usage;

(iii) Develop a statistical model to analyze the relationship between individual attributes and information characteristics including different information sources under no-notice evacuation situations.

1.3 Organization of the research

The remainder of the paper is organized as follows. The next section describes previous studies on using SNS to assist EMAs during no-notice evacuations. Then, the survey design and implementation for this study are discussed. After that, the descriptive statistics of the raw data for this survey is described. Next, the modeling methods used to understand the correlation between individual's socio-economic and behavioral characteristics, and their SNS usage behavior during no-notice evacuations are discussed. Then, the insights from survey and models are provided. The paper concludes with some comments and insights.

CHAPTER 2. LITERATURE REVIEW

There is a vast body of literature on using SNS to assist EMAs during a no-notice evacuation. Based on the role of SNS in a no-notice evacuation, previous studies can be classified into three types: to understand how EMAs use SNS to disseminate disaster and evacuation related information, to study how EMAs monitor the disaster and evacuation related information on SNS to design faster response, and to investigate how EMAs can diffuse and/or control the disaster and evacuation related information on SNS.

To understand how EMAs can use SNS to disseminate information during no-notice disasters, efforts are made to develop methods to use SNS to effectively deliver disaster and evacuation related information to more people. For example, some studies (Veil et al., 2011; Athanasia and Stavros, 2015) proposed to utilize SNS to improve the preparedness of evacuation, recruit volunteers and provide support to evacuees. Other studies focused on determining the types of information based on the targeted audiences to eliminate or reduce negative consequences caused by usage of SNS (Wendling et al., 2013; Simon et al., 2015).

In terms of studying how EMAs can monitor disaster and evacuation related information on SNS to design faster response, previous studies (Wendling et al., 2013; Simon et al., 2015) found that the monitoring process can be summarized into the following steps: collect information matching a given criterion on SNS, process natural language, extract information, monitor information volume, group information and translate information. Efforts were made to develop different methods to translate information on SNS. For example, some studies used various data mining methods to identify recent public interest or important information related to disaster and/or evacuation on SNS (Mendoza et al., 2010; Acar and Muraki, 2011; Blanford et al., 2014; Olteanu et al., 2014; Ukkusuri et al., 2014) and visualize the results on the map (Graham et al., 2014; Middleton et al., 2014). Based on the information collected, EMAs can identify the change of public focus during the no-notice evacuation. In addition, the information collected can be used to help

EMAs to get updated information such as infrastructure damage and casualties (Ashktorab et al., 2014). Some studies (Mandel et al., 2012; Yin et al., 2012) developed time series graphs using the volume of the disaster and evacuation related information over time to show the degree of public interest in a no-notice evacuation. Other studies (Kryvasheyeu et al., 2015; Lee et al., 2015; Gurman and Clark, 2016) focused on developing methods to identify active users on SNS so that disaster and evacuation related information can be disseminated faster, but some studies (Cheong and Cheong, 2011) found that active users on SNS in one no-notice evacuation may not be as active as they were in another evacuation, which makes identifying active users hard to apply in real-world emergency management strategies. One of the main reason such difference exists is that whether people post/repost or not (i.e. active on SNS) in a no-notice evacuation depends on their levels of trust towards their information sources and their SNS usage behavior which is often correlated with their socio-economic and behavioral characteristics. However, few studies have explored why people post/report in a no-notice evacuation and how this is correlated with their socio-economic and behavioral characteristics.

Most studies related to diffusing and/or controlling the disaster and evacuation related information on SNS focused on modeling the information diffusion on SNS. The independent cascade models and the linear threshold models are the most widely used model. In independent cascade models, information diffuses through the connections between users on SNS, which is similar to cascades of infections, while in linear threshold models, information diffusion speed depends on the thresholds of the influence from followees on SNS (Bourigault et al., 2016). However, little efforts have been made to understand why certain disaster or evacuation related information is post/repost on SNS.

The aforementioned studies address how SNS can be used to assist EMAs to disseminate, monitor and diffuse/control disaster and evacuation related information during no-notice evacuations. However, they do not address the potential differences in terms of people’s levels of trust towards the same information from SNS, traditional communication platforms, people they know and strangers nearby during no-notice evacuations. The potential impacts of people’s levels of trust towards information from

different accounts on posting/reposting behavior have not been addressed. In addition, they do not capture why people post/repost disaster and/or evacuation related information on SNS, whether they check SNS once getting disaster and/or evacuation related information, what levels of posting/reposting frequency they will choose during a no-notice evacuation and how this choice is correlated with their socio-economic and behavioral characteristics. In this study, people's levels of trust towards the information of disaster occurrence notification and evacuation recommendation on SNS are studied and compared to their levels of trust towards the same information from other sources, including traditional platforms (Purdue Alert and strangers in uniform), people they know and strangers nearby using a survey of people in Purdue University West Lafayette campus. People's levels of trust towards different accounts on SNS, including accounts of news media, organization or institution, followees participants know personally, followees participants don't know personally, celebrities and others, are also studied. In addition, the correlation between people' socio-economic and behavioral characteristics and their choice to not posting/reposting, posting/reposting as usual, or posting/reposting more frequently during a no-notice evacuation is examined.

CHAPTER 3. STATED PREFERENCE SURVEY

3.1 Survey description

The relationship between people's SNS-related behaviors in no-notice evacuations, and the factors that influence these behaviors are investigated using a survey of students, staffs and faculty members in Purdue University West Lafayette Campus in the U.S. This survey was conducted using online questionnaire distributed via emails. The details of the survey can be accessed via https://purdue.qualtrics.com/jfe/form/SV_died8aIRw4GW6z3. The contact information was retrieved via websites of different departments of Purdue University and internet searches. All participants must be over 18 years old. A total of 3323 surveys were distributed in 2016.

The purpose of the survey is to explore people's SNS-related behaviors, including their levels of trust towards information of disaster occurrence notification and evacuation recommendation from SNS, respectively, and SNS usage when faced with a no-notice evacuation (e.g. a radiation leak) on campus. The survey questions were classified into five sections: everyday SNS usage, levels of trust towards the same information from different information sources, SNS usage during a no-notice evacuation, ranking the trustworthiness of the same information from different sources, and general information.

The first part of the survey was used to capture the participants' everyday SNS usage. Of primary interest are whether people use SNS, and the frequencies of checking and posting/reposting on SNS. The second part of the survey was designed to understand participants' SNS-related behaviors, including levels of trust towards the same information from five different information sources, and whether they will check additional information on SNS if that source is the first source they get the information from. Note that information of disaster occurrence notification and evacuation recommendation can be disseminated several times with updated information during a no-notice evacuation. That information is designed as "There is a radiation leak on Purdue West Lafayette Campus and the whole campus will be affected. Leave the campus." , and disseminated only once by each

information source in the survey to reduce its influence on people's SNS-related behaviors. Five information sources are Purdue Alert (Purdue University's emergency warning notification system), someone that participants know, strangers in uniform, strangers not in uniform and SNS. Purdue Alert, which follows the Federal Emergency Management Agency's (FEMA) 'Comprehensive Emergency Management Program Model', provides a multi-layered communication approach that formalizes Purdue University's emergency warning notifications. When a no-notice disaster happens, the system delivers evacuation-related information to people using multiple platforms, including hazards outdoor warning sirens, information displaying on logged in computers, text message to those who have signed up for Purdue Alert, followers of Purdue Alert's Twitter account (@purdueemergency) and everyone with Purdue Email (Purdue university, 2015a). Questions were also asked about participants' levels of trust towards the disaster occurrence notification and evacuation recommendation on SNS if they come from different types of SNS accounts. These accounts include news media accounts, followees participants know personally (followee is a person who is being tracked on SNS), followees participants do not know personally, accounts of institution or organization, accounts of celebrities, and other accounts. Participants were requested to select their levels of trust towards information from these sources on a five-point Likert scale ranging from "Definitely will not" (=1) to "Definitely will" (=5).

The third part of the survey was used to understand people's three types of behaviors during a no-notice evacuation, namely SNS checking behavior, communication behavior and SNS posting/reposting behavior. SNS checking behavior is about the participants' behavior of checking information on SNS during a no-notice evacuation. It includes whether participants check information on SNS or not, and whether they check more frequently than usual in a no-notice evacuation. Communication behavior is defined as the participants' willingness of word-of-mouth communication with others about the information of disaster occurrence notification and evacuation recommendation. SNS posting/reposting behavior includes when to post/repost on SNS, whether to post/repost more frequently than usual, what to post/repost and why to post/repost.

The fourth part of the survey was designed to understand the trustworthiness and importance of the same information from six sources, including SNS, what participant sees with his/her own eyes, someone that he/she knows, strangers not in uniforms, strangers in uniforms, and Purdue Alert. Participants were asked to rank these sources based their perspectives in terms of the trustworthiness and importance of the same information from these sources. The last part of the survey was about the general information of participants, including their gender, age, Purdue affiliation and nationality.

3.2 Data characteristics

A total of 305 completed surveys were obtained with an overall response rate of 9.18%. Table 1 illustrates general information of the participants. Among all participants, there are slightly more female participants (51.48%) than male participants (48.52%), and nearly half of participants are under 35 years old. 26.56% of participants are not U.S. citizens which is close to 23.21% reported by Purdue International Students and Scholars Department (Purdue University, 2015b). Students and staff members each represents about 40% of participants and the rests are faculty members. These show that participants included can be considered as a representative sample of Purdue University, because no significant differences were observed in terms of the portions of students, staff members and faculty members between participants and the Purdue University in fall 2015.

Table 2 presents participants' SNS usage behavior. A key observation is that over 80% of the participants use SNS, which is higher than the National average (65%) (Perrin, 2015). A possible reason is that although the recruitment e-mails were sent randomly, people who decided to participate in the survey might be more interested in SNS than those did not, hence, majority of our respondents use SNS. Among those who use SNS, about 80% of them use SNS daily, but most of them (86.7%) post/repost less than once a day.

Among non-SNS users, including those who quitted using SNS or have never used SNS, the top two reasons of not using SNS are "Using SNS is a waste of time" (64.91%) and "SNS may violate their privacy" (42.11%). Only 12.28% of them do not use SNS because of their low levels of trust towards SNS, which indicates that even among non-

SNS users, majority of them trust the information on SNS. About 30% of non-SNS users choose “other” and write down their reasons of not using SNS. Their reasons can be summarized into three types, including having enough communication platforms, not wanting the information on SNS to shape their perceptions, and not wanting to get distract from their own business.

Table 3 shows participants’ levels of trust towards information of disaster occurrence notification and evacuation recommendation from different sources, respectively. In terms of information with same content from different sources, Purdue Alert is considered as the most trustworthy information source for both information of disaster occurrence notification and evacuation recommendation by participants (4.78 and 4.73, respectively), while strangers not in uniform are considered as the least trustworthy information source. The results also show that participants have very similar levels of trust towards information of disaster occurrence notification and evacuation recommendation from the same source except for information from someone they know. As illustrated in Table 3, participants trust the information of disaster occurrence notification from someone they know (3.88) more compared to the same information from strangers in uniforms (3.57), while they trust evacuation recommendation from someone they know (3.94) less than that from strangers in uniforms (4.05). It suggests that people value the evacuation recommendation from someone in uniform more compared to someone they know, because they considered someone in uniform as an expert on evacuation, hence, evacuation recommendation from someone in uniform is more trustworthy. Although SNS are considered as the fourth trustworthy information source among all five sources, more people consider information of disaster occurrence notification and evacuation recommendation from SNS trustworthy than those who do not.

Participants were also asked to describe their SNS checking behavior when they first get information of disaster occurrence notification from each source. As illustrated in Table 3, most of participants want to get more information from SNS if they first get the information from Purdue Alert, someone that participants know, strangers not in uniform and SNS. It shows that people want to access information from different sources in a no-

notice evacuation. One possible reason is that getting information from various sources can help people make more informed decisions in a no-notice evacuation. This also indicates the importance of using SNS to assistant EMAs and disaster-affected people in no-notice evacuation, because often other information sources (e.g. someone they know) may not be available during the evacuation.

Participants' levels of trust towards information from different accounts on SNS were also discussed. In Table 3. Among the given accounts on SNS, news media accounts are considered as the most trustworthy information source, followed by the accounts of organizations and institutions. This indicates that people trust information from the reputations and credibility of organizations, institutions and authorities on SNS more compared to information from their followees and celebrities in a no-notice evacuation.

SNS users' posting/reposting behaviors during a no-notice evacuation were illustrated in Table 4. Among 248 SNS users, about 50% of them will post/repost during a no-notice evacuation. Among those who will post/repost on SNS, after complete evacuation (63.85%), after checking information on SNS (40%), and after making decision on whether to evacuate (38.46%) are the top three moments that they are most likely to post/repost. Nearly 50% of them will post/repost more than once during the evacuation. It indicates that most SNS users are willing to spread information of disaster occurrence notification and evacuation recommendation during a no-notice evacuation, and they are most likely to post/report after they complete evacuation and reach to a safer location. Among those who will post/repost on SNS, information from Purdue Alert (35.66%), accounts of organization or institution on SNS (20.93%), from what participants see with their own eyes (18.60%), and from news media on SNS (17.05%) are the top four information that they are willing to post/repost. This result indicates that most potential evacuees will be more likely to post/repost information they received from traditional channels (e.g. Purdue Alert) and accounts of organizations or institutions on SNS compared to what they observe. This indicates that the accuracy and timelessness of the information delivered by EMAs, through either traditional communication platforms or official accounts on SNS, is critical to information dissemination on SNS.

In terms of why to post/repost on SNS, a majority of participants disseminate the information because they think it is important to their followees (79.23%) and they want to spread the information widely (60.77%). It indicates that during a no-notice evacuation, people are more likely to post/repost on SNS because they want to spread the information of disaster occurrence notification and evacuation recommendation to more people and hope the information can help others make their evacuation decisions. Thus, besides the accuracy and timelessness of the information, EMAs should also consider people's perceived importance of posting/reposting the information on SNS to foster information dissemination on SNS.

Table 1. Socio-economic characteristics of participants

Attribute	Percentage
Gender	
Male	48.52
Female	51.48
Age	
18-24	17.05
25-34	32.46
35-44	13.77
45-54	16.72
Older than 55	20.00
Purdue affiliation	
Student	40.33
Staff	36.39
Faculty	23.28
Citizenship	
U.S. citizen	73.44
International	26.56
Evacuation experience	
Have experience	52.13
No experience	47.87

Table 2. SNS usage behavior of participants

Attribute	Percentage
SNS usage	
Use SNS	81.31
Quit SNS	10.49
Never use SNS	8.20
Frequency of SNS usage (for those who use SNS now)	
Less than once a week	10.34
2-6 times a week	9.85
Once a day	16.26
More than once a day	63.55
Frequency of posting/reposting on SNS (for those who use SNS now)	
Less than once a month	26.11
Once or twice a month	30.05
Once a week	17.24
2-6 times a week	13.30
At least once a day	13.30

It wastes time	57.69	70.97	64.91
To protect privacy	42.31	41.94	42.11
Others	34.62	25.81	29.82
Too many advertisements	15.38	9.68	15.79
Do not trust information on SNS	11.54	19.35	12.28

Table 3. Levels of trust towards information from different sources

Related survey items (questions)	Answers	
Levels of trust towards information from these sources among all participants (Average value)		
	disaster occurrence notification	Evacuation recommendation
Purdue Alert	4.78	4.73
Someone participants know	3.88	3.94
Strangers in uniforms	3.57	4.05
SNS	3.41	3.26
Strangers not in uniforms	2.63	2.66
Whether to check SNS for more information if first get information from these sources among SNS users (Percentage)		
	Yes	No
SNS	79.59	20.41
Strangers not in uniform	65.31	34.69
Someone participants know	58.00	42.00
Purdue Alert	51.02	48.98
Strangers in uniforms	48.98	51.02
Whether to trust information from these accounts on SNS among SNS users (Percentage)		
	disaster occurrence notification	Evacuation recommendation
News media	80.07	73.20
Organization or institution	71.24	70.59
Followees participants know personally	45.75	41.83
Followees participants don't know personally	6.54	5.56
Celebrities	3.92	2.61
Others	3.27	2.94

Table 4. SNS users' Posting/reposting behavior during a no-notice evacuation

Attribute	
Whether to post/repost on SNS among SNS users	
Yes	49.20
No	50.80
Frequency to post/repost on SNS among those who will post/repost on SNS	
More frequently	55.47
Post/repost but not more frequently	44.53
When to post/repost on SNS among those who will post/repost on SNS (Multiple choice)	
Before checking information on SNS	2.31
After checking information on SNS	40.00
Before making decisions on whether to evacuate	11.54
After making decisions on whether to evacuate	38.46
During their evacuation if they decide to evacuate	22.31
After their evacuation if they decide to evacuate	63.85
What to post/repost on SNS among those who will post/repost on SNS	
Purdue Alert	35.66
Information from accounts of organization or institution	20.93
What I see with my own eyes	18.60
Information from news media accounts	17.05
Information from people in uniforms	3.10
Information from followees I know personally	3.10
Information from strangers (not in uniform) nearby	0.78
Information from someone you know	0.78
Why to post/repost on SNS among those who will post/repost on SNS (Multiple choice)	
It's important to others.	79.23
It can be spread widely.	60.77
It can be reposted by others.	23.85
This information is posted or reposted by accounts I trust.	23.08
It's important to myself.	11.54
Most of my followees post/repost such information.	8.46
It includes pictures or videos.	8.46
Others	6.15
It can get more thumbs up.	3.85

CHAPTER 4. MODEL DEVELOPMENT AND DATA ANALYSIS

4.1 Mixed logit model

To model the correlation between people's socio-economic characteristics and their SNS usage behavior, and their posting/reposting choice (not posting/reposting, posting/reposting as usual, or posting/reposting more frequently) during a no-notice evacuation, a mixed logit model is estimated. The mixed logit model represents a generalized multinomial logit model with random parameters $\beta_{in}|\varphi$. φ represents a vector of parameters of the chosen density function and β represents the parameter vectors. Mixed logit model allows β to vary across observations to account for unobserved heterogeneity. The mixed logit model can be written as (Washington et al., 2010; Guo and Peeta, 2015; Guo et al., 2016):

$$P_i(n|\boldsymbol{\varphi}) = \int \frac{e^{\boldsymbol{\beta}_{in}\mathbf{X}_{in}}}{\sum_{\forall I} e^{\boldsymbol{\beta}_{in}\mathbf{X}_{in}}} f(\boldsymbol{\beta}_{in}|\boldsymbol{\varphi}) d\boldsymbol{\beta}_{in} \quad \text{(Eq.1)}$$

where, $P_i(n|\boldsymbol{\varphi})$ is the probability of a user i make posting/reposting choice n conditional on $f(\boldsymbol{\beta}_{in}|\boldsymbol{\varphi})$. If the variance in $\boldsymbol{\varphi}$ is significantly different from zero, there will be respondent-specific variations of effect of $\mathbf{X}$ on the choice n.

The mixed logit model (Eq.1) can be estimated using the simulated maximum likelihood approach by drawing β_{in} from $f(\beta_{in}|\varphi)$ for given values of φ. Normal, lognormal, triangular, uniform, and Weibull distributions are considered for the function forms of the parameter density function.

One key element of the methodology relies on how the factors affect the posting/reposting behavior. Elasticities are used to assess the effect of parameter estimates on the probability of people make their posting/reposting choice through an analytical approach. It can be interpreted as the percent effect of given a 1% change in one factor on the probability of people make their posting/reposting choice. Equation 2 is used to compute elasticities for each user i (Nowrouzian and Srinivasan, 2012; Guo and Peeta, 2015).

$$E_{x_{ink}}^{P_i(n|\boldsymbol{\varphi})} = \frac{\partial P_i(n|\boldsymbol{\varphi})}{\partial x_{ink}} \times \frac{x_{ink}}{P_i(n|\boldsymbol{\varphi})} \quad \text{(Eq.2)}$$

where $E_{x_{ink}}^{P_i(n|\varphi)}$ is the elasticity of user *i* and x_{ink} is the value of variable *k* for user *i*.

4.2 Estimation results

Model estimation results of factors that affect people's posting/reposting behavior on SNS during a no-notice evacuation are presented in Table 5. Only those who are using SNS (n = 248) are included in the model estimation. All random parameters are normally distributed. 10 independent variables were found to be statistically significant ($t \geq 1.69$), including two related to people's socio-economic characteristics (evacuation experience and male indicators), two variables related people's SNS usage behavior (frequent SNS user and frequent posting/reposting indicators), three variables related to people's levels of trust towards information on SNS (trusting information on SNS, trusting recommendation on SNS, and trusting SNS accounts indicators), three variables related to SNS checking behavior (checking SNS, moment to check SNS and frequent checking SNS indicators), and two variables related to people's levels of trust towards information from sources other than SNS (trusting someone participants know and trusting information from traditional platforms indicators). In this study, traditional communication platforms include Purdue Alert and strangers in uniform. The model's estimation results are discussed based on the direct and cross marginal effects for statistically significant variables that affect people's posting/reposting behavior during a no-notice evacuation. If an independent variable belongs to multiple utility functions, its impacts on people's posting/reposting behavior during a no-notice evacuation are analyzed by summing up its the marginal effects in those utility functions (Nowrouzian and Srinivasan, 2012).

Table 5. Mixed logit model for posting/reposting behavior on SNS

Variable	Parameter estimate	*t*-Statistic	Elasticities (%)		
			NP	MF	NF
Factors for not posting/reposting on SNS (NP)					
Constant	-4.29	-4.05			
Frequent SNS user indicator (1, if an individual uses SNS daily; 0, otherwise)	-0.28	-2.03	-0.97	0.27	0.27
Trusting information on SNS indicator (1, if an individual "definitely will" or "probably will" trust information of disaster occurrence notification on SNS; 0, otherwise)	1.21 (1.41)	2.29 (3.70)	0.57	-0.16	-0.26
Checking SNS indicator (1, if an individual "definitely will" or "probably will" check his/her SNS no matter which source he/she first gets the information about the disaster occurrence notification or evacuation recommendation from; 0, otherwise)	0.34	2.53	0.53	-0.16	-0.17
Factors for posting/reposting more frequently on SNS (MF)					
Frequent posting/reposting indicator (1, if an individual posts/reposts on SNS more than once a day; 0, otherwise)	0.21	1.78	-0.14	0.37	-0.18
Trusting SNS accounts indicator (1, if an individual "definitely will" or "probably will" trust both information of disaster occurrence notification and evacuation recommendation from at least one account on SNS; 0, otherwise)	0.81	1.74	-0.04	0.15	-0.05
Trusting recommendation on SNS indicator (1, if an individual "definitely will" or "probably will" trust evacuation recommendation on SNS; 0, otherwise)	0.54	2.46	-0.41	1.27	-0.54
Trusting information from traditional platforms indicator (1, if an individual "definitely will" or "probably will" trust disaster occurrence notification information from both Purdue Alert and strangers in uniform; 0, otherwise)	0.83	4.54	-0.81	2.88	-1.09
Frequent checking SNS indicator (1, if an individual "definitely will" or "probably will" check SNS more frequently after knowing about the disaster; 0, otherwise)	0.46	4.40	-0.28	0.44	-0.38
Trusting someone participants know indicator (1, if an individual "definitely will" or "probably will" trust both information of disaster occurrence notification and evacuation recommendation from someone he/she knows; 0, otherwise)	0.96	1.69	-0.03	0.13	-0.04
Check SNS after decision indicator (1, if an individual checks SNS after he/she made evacuate decision; 0, otherwise)	1.09	2.93	-0.09	1.30	-0.12
Factors for posting/reposting but not changing the frequency on SNS (NF)					
Evacuation experience indicator (1, if an individual has evacuation experience; 0, otherwise)	-1.81	-2.31	2.32	1.84	-2.76
Male indicator (1, if an individual is male; 0, otherwise)	0.98	2.57	-0.24	-0.38	0.37
Log-likelihood(convergence)			-294.40		
Log-likelihood(initial)			-272.51		
ρ^2			0.08		
Number of observations			248		

Note that for a random parameter, the number shown in parentheses for a parameter estimate denotes its standard deviation, and number in parentheses for the t-statistic denotes the random parameter's t-statistic

4.2.1 **Socio-economic characteristics**

Two indicator variables (evacuation experience and male indicators) related to an individual's socio-economic characteristics are found to be statistically significantly correlated with his/her posting/reporting behavior in a no-notice evacuation. The marginal effects analysis shows that if an individual has evacuated before, he or she is more likely to not post/repost on SNS (2.32%) or to post/repost more frequently (1.84%) during a no-notice evacuation. A possible reason of this diverse posting/reposting behavior existing among people with evacuation experience is that their perceptions towards whether the evacuations they experienced are necessary are difference. Previous studies have identified the so called "crying wolf" effect that repeated false alarms can potentially reduce the credibility of warning information and make people to become more reluctant to evacuation (Barnes et al., 2007). Similarly, if an individual perceives his/her previous evacuations are unnecessary and/or the information of the disaster occurrence notification and evacuation recommendation is false alarm, he or she is less likely to value the importance of spreading information of the disaster occurrence notification and evacuation recommendation, and choose to not post/repost in a no-notice evacuation. If an individual perceives his/her previous evacuations are necessary and/or the information of the disaster occurrence notification and evacuation recommendation is important in their evacuation decision-making process, he/she is likely to value more about the importance of spreading information of the disaster occurrence notification and evacuation recommendation, and choose to posts/reposts more frequently in a no-notice evacuation.

The results also show that males are more likely to post/repost on SNS but not to changing their frequency to post/repost in a no-notice evacuation. A possible reason is that males are less likely to change their posting/reposting behavior when the situation they are in or the information they received changes compared to females.

4.2.2 **SNS usage behavior**

Frequent SNS user and frequent posting/reposting indicators, are found to be statistically significantly correlated with one's posting/reporting behavior in a no-notice evacuation. The marginal effects analysis shows that an individual who uses SNS at least

once a day is more likely to post/repost (either more frequently or as frequent as usual) on SNS during a no-notice evacuation. A possible reason is that those people who use SNS frequently are considered to be less emotionally stable (Correa et al., 2010), and people with unstable emotions are more likely to post/repost on SNS than stable ones (Celli and Rossi, 2012).

In addition, if an individual post/report at least once a day, he or she is more likely to post/repost more frequently in a no-notice evacuation. It shows that people who post/report more in their daily life are also likely to be more active in spreading the information of the disaster occurrence notification and evacuation recommendation. It can support EMAs to find out potential active users to accelerate information dissemination.

4.2.3 **Levels of trust towards information on SNS**

Three variables (trusting information on SNS indicator, trusting recommendation on SNS indicator, and trusting SNS accounts indicator) related people's levels of trust towards information on SNS are found to be statistically significantly correlated with their posting/reposting behavior in a no-notice evacuation. The marginal effects analysis shows that people who "definitely will" or "probably will" trust disaster occurrence notification information on SNS are less likely to post/repost on SNS during a no-notice evacuation. It indicates that trusting information of disaster occurrence notification on SNS alone do not lead to posting/reposting on SNS. Those who "definitely will" or "probably will" trust the evacuation recommendation on SNS are more likely to post/repost more frequently on SNS during a no-notice evacuation. It indicates that an individual is only convinced about the necessity of posting/reposting if he/she trusts information of evacuation recommendation on SNS, while just trusting information of disaster occurrence notification on SNS is not sufficient to convince him/her to post/repost. A possible reason is that people choose to post/repost certain information on SNS based on not only their levels of trust towards the information but also on their perceived importance of spreading the information on SNS, and in a no-notice evacuation, people value more about spreading information of evacuation recommendation on SNS compared to spreading information of disaster occurrence notification.

The results show that if an individual “definitely will” or “probably will” trust both information of the disaster occurrence notification and evacuation recommendation from at least one account on SNS, he/she is more likely to post/repost more frequently on SNS during a no-notice evacuation. It indicates that if an individual has a higher levels of trust towards some accounts on SNS, he/she is more likely to post/repost more frequently during no-notice evacuations. Therefore, the credibility of an account is critical in determining how fast and how wide the information spreads on SNS during a no-notice evacuation. This indicates that if an SNS account repeatedly publish perceived false alarm, the information disseminated by that account may not reach fast or wide on SNS. As shown in section “data characteristics” before, people trust information from reputations and credibility of organizations, institutions and authorities on SNS more. EMAs can improve their own reputations and credibility to motivate individuals to post/repost information on SNS so that information of the disaster occurrence notification and evacuation recommendation can be spread to wider users faster during a no-notice evacuation.

4.2.4 **SNS Checking behavior**

Three variables related to SNS checking behavior (checking SNS, moment to check SNS and frequent checking SNS indicators) are found to be statistically significantly correlated with one’s posting/reporting behavior in a no-notice evacuation.

The marginal effects analysis indicates that an individual, who “definitely will” or “probably will” check SNS for more information no matter which source he/she first gets the information about the disaster occurrence notification or evacuation recommendation from, is more likely not to post/repost on SNS. A possible reason is that an individual, who requires information from multiple sources to assess the situation, is also cautious about the information they are sharing on SNS. Another possible reason is that they may just consider SNS as information source instead of an information sharing platforms, so they only check SNS for more information no matter from which source they first get information, but not sharing information on SNS.

The marginal effects analysis shows if an individual checks SNS after he/she made an evacuation decision, he/she is more likely to post/repost more frequently during no-

notice evacuations. A possible reason is that people who check SNS after making evacuate decisions may be more likely to seek specific types of information related to the evacuation decision they made (e.g. information that supports the evacuation decision they made), and they are more likely to share their decisions and/or the comparison between their decisions and the information they gathered on SNS. Thus, they are more likely to post/repost more frequently than usual. In addition, it also indicates that there may be a correlation between people's evacuation decision-making process and their posting/reposting behavior, and more efforts should be made to understand it.

Frequency to check SNS during a no-notice evacuation is also a factor that affects the posting/reposting behavior. The marginal effects analysis showed that if an individual "definitely will" or "probably will" check SNS more frequently after knowing about the disaster, he/she is more likely to post/repost more frequently during no-notice evacuations. One possible reason of this phenomena is that people check SNS for information but they may not post/repost until they find something capturing their interest (Xu and Yang, 2012). Those who check SNS more frequently are more likely to find information drawing their attention, thus, more likely to post/repost more frequently compared to those who do not check SNS frequently. Therefore, it is critical for EMAs to monitor the information on SNS during no-notice evacuations to identify interests of target audience (e.g. people suffering power shortage or people need shelter) and use them to design information so that information can be disseminated to a larger audience faster.

4.2.5 **Levels of trust towards information from sources other than SNS**

Trusting someone participants know and trusting information from traditional platforms indicators are two variables to show levels of trust towards other sources. The marginal effects analysis shows that if an individual "definitely will" or "probably will" trust information of the disaster occurrence notification and evacuation recommendation from someone he/she knows, he/she is more likely to post/repost more frequently on SNS. If an individual "definitely will" or "probably will" trust information about the disaster occurrence notification from traditional platforms, he/she is more likely to post/repost more frequently on SNS. It indicates that levels of trust towards information from sources other

than SNS would influence the posting/reposting behavior on SNS during a no-notice evacuation. A possible reason is that if an individual trusts some specific sources (e.g. someone he/she know) in real life, he/she may be more likely to post/repost information from those sources' SNS accounts.

CHAPTER 5. CONCLUDING COMMENTS

This study provides a statistical analysis of people's posting/reposting behavior on SNS during a no-notice evacuation. To achieve this, a survey of people in Purdue West Lafayette Campus was conducted to gain insights on people's levels of trust towards information from different sources, (Purdue Alert, someone that participants know, strangers in uniform, strangers not in uniform and SNS) and factors that influence their frequency to post/repost on SNS during a no-notice evacuation. Based on the descriptive statistics, the ranking from the most trustworthy information source about disaster occurrence notification to the least is Purdue Alert, someone that participants know, strangers in uniform, SNS and strangers not in uniform. In terms of people's levels of trust towards information about evacuation recommendation from different sources, strangers in uniform is ranked higher than someone that participants know, while the rest of the ranking remains the same. Note that despite SNS ranks fourth among five different sources, a majority of people trust information from SNS and SNS may be the only information source available during a no-notice evacuation due to the unavailability or inaccessibility of the first three sources. People also show different levels of trust towards different types of accounts on SNS, and the reputations of the organizations, institutions and authorities can influence the levels of trust towards the information disseminated by accounts of them on SNS. The descriptive statistics also show that half of the participants may not post/repost information of the no-notice evacuation on SNS. Mixed logit model was used to understand the factors that impact people's posting/reposting frequency during a no-notice evacuation.

As illustrated by Table 5, ten characteristics, including two related to people's socio-economic characteristics (evacuation experience and male indicators), two variables related people's SNS usage behavior (frequent SNS user and frequent posting/reposting indicators), three variables related to people's levels of trust towards information on SNS (trusting information on SNS, trusting recommendation on SNS, and trusting SNS accounts indicators), three variables related to SNS checking behavior (checking SNS, moment to check SNS and frequent checking SNS indicators), and two variables related to people's

levels of trust towards information from sources other than SNS (Trusting someone participants know and trusting information from traditional platforms indicators), have strong statistically significant correlation with people's posting/reposting frequency during a no-notice evacuation. In addition, by using mixed logit model, heterogeneity was found across people based on the random parameter variations.

The various findings and insights can be used to assist EMAs in designing information dissemination strategies on SNS during a no-notice evacuation that captures people's posting/reposting behavior in the evacuation, including: (i) using SNS as complementary information dissemination platforms during a no-notice evacuation is feasible and even critical to ensure information of disaster occurrence notification and evacuation recommendation being delivered to a larger audience faster, especially in situations where traditional platforms are inefficient and/or insufficient; (ii) improving the reputation of EMAs to increase people's levels of trust towards the information from their accounts on SNS; (iii) reducing false alarms or perceived false alarms disseminated through both traditional platforms and SNS to improve people's levels of trust towards the information of disaster occurrence notification and evacuation recommendation; (iv) understanding why people perceive certain information of disaster occurrence notification and evacuation recommendation is important to spread is critical in motivating people to disseminate information during no-notice evacuations; (v) monitoring the information on SNS during no-notice evacuations to understand target audience's interest and adjusting information based their interest to increase information dissemination speed; (vi) identifying potential active users on SNS during no-notice evacuations based on their SNS posting/reposting frequency. A potential future research direction discovered in this study is to understand the correlation between people's evacuation decision-making process and their posting/reposting behavior on SNS during a no-notice evacuation.

Given that the content of information of disaster occurrence notification and evacuation recommendation is same no matter which source that information is from in the survey, the results of the model cannot offer a picture of people's SNS-related behavior when they get inconsistent information from different sources during no-notice

evacuations. Furthermore, the designed content of information includes disaster type (a radiation leak), affected area (the whole campus) and evacuation recommendation (leave the campus). Whether that content is enough to make people aware of their situations and take actions or not is not analyzed in this study. Further research intends to consider the inconsistent information from different sources, which may help EMAs to control rumor spreading on SNS during no-notice evacuations.

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