# Factors Affecting Flood Evacuation Decision and Its Implication to Transportation Planning

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**Abstract**: Evacuation decision during flood disasters indicates the choice of households to evacuate or stay from area at risk. This may be viewed as simple decision but involves complex behavioral and other external factors. Evacuation decision serves as key input to transportation planning in the event of flood, hence, careful consideration of the factors that determine this decision should be done. Such factors include broadly the characteristics of households and their capacity as well as risk-related factors. This review identifies the factors by bringing together findings from viewpoint of evacuation managers and social scientists as well as transportation planners. Further research is needed to identify the interrelationships of these factors for consideration in evacuation transportation planning and modeling.

*Keywords*: Flood, Evacuation Decision, Transportation Planning, Risk, Capacity

## 1. INTRODUCTION

Disasters, natural or man-made, such as hurricanes, floods, major chemical accidents, and conflicts may come in unlimited diversities. It is the event that "causes serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of the affected people to cope using their own resources" (Abarquez, 2004). It has been evident that disasters are becoming more frequent and have been causing severe and tremendous damages to the people, economy, and properties (e.g. Allen, 2006; Torrente *et al.*, 2008). In order to minimize the impacts of disasters, emergency planning and preparedness measures are necessary.

Evacuation is considered a way to prepare people when at risk from an impending hazard (Taylor and Freeman, 2010). It is an important part of disaster management and is an effective way of minimizing loss of lives and property damage (Na *et al.*, 2012). It is considered a process (as presented in Figure 1) that constitutes hazard detection, issuance of warning, preparation to evacuate, movement to identified shelters through a network (Stepanov and Smith, 2009), and reentry to the community after disaster (EMA, 2005). In addition, the process comprises route assignment and management approaches, providing emergency-related services as well as attending to people with special needs such as the elderly and disabled, and coordination and management of evacuation fleets (Hsu and Peeta, 2012). Transportation, therefore, is particularly important to these operations. Transportation planning during evacuation (referred to as evacuation planning in the rest of the paper), from traffic demand generation, scheduling of movement, to network flow assignment towards identified shelters and to mention the reentry to households' homes after the occurrence of

disaster, is crucial for effective evacuation process.

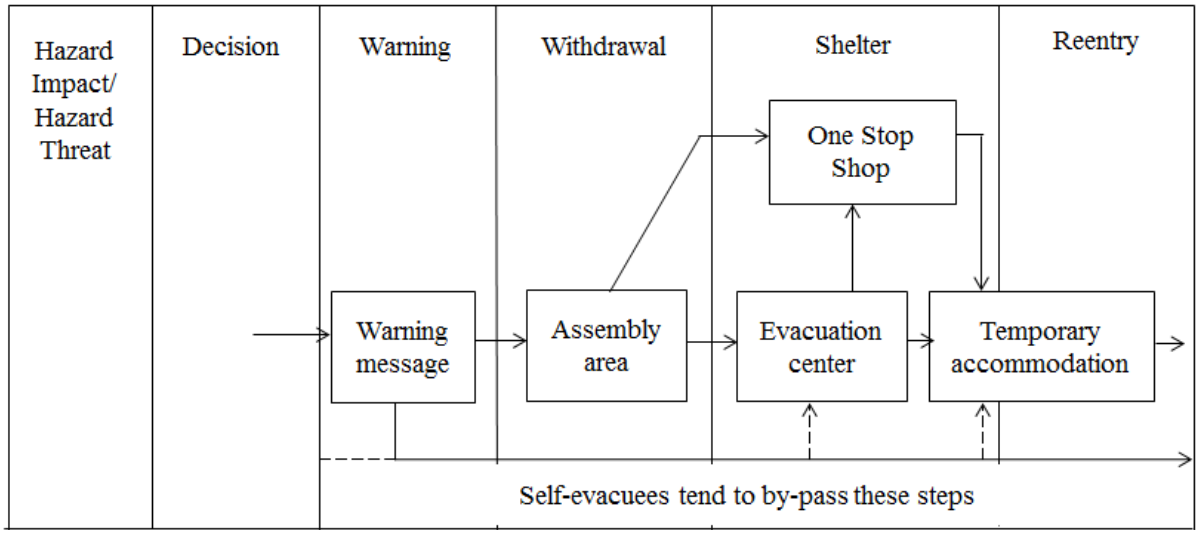


Figure 1. Evacuation process model
Source: EMA (2005)

In evacuation planning and operations, inputs from various decision makers involved such as individuals/households and the authorities (e.g. evacuation managers and transport planners) are necessary (Smith and Stepanov, 2009). For instance, in the part of authorities, the issuance of evacuation notice encompasses identification of areas to be evacuated, successive order of moving out from the areas, and the preparations and arrangements for shelters (Hsu and Peeta, 2012). This and other aspects of decision-making need strategic actions to produce effective outputs (Smith and Stepanov, 2009).

On the other hand, individuals/households are involved in evacuation decision, which is their choice to evacuate or stay in the area under risk. Evacuation decision involves complex behavioral factors influencing individuals/households of various characteristics and situations at the period of choosing (Simonovic and Ahmad, 2005). The evacuation decision is very important input to evacuation planning and modeling. Thus, identifying and analyzing the complex factors affecting the evacuation decision is crucial for better planning and evacuation operations. A behaviorally-sound evacuation modeling is important for smooth execution of evacuation during the event of disasters. In this case, chaos, delays in transporting evacuees, and other transport-related issues would be minimized (Siebeneck, *et al.*, 2013).

Most of the time, individuals/households do not prefer mandatory evacuation (Taylor and Freeman, 2010). However, in practical cases, they are encouraged to evacuate when they see indications of the hazard, and when their home is under danger (Siebeneck and Cova, 2012). The nature of the hazard, the risk posed by the hazard and how individuals/households perceive them is a growing subject especially in social science research. However, its relationship to evacuation decision is yet to be fully explored most especially its implications to evacuation planning and modeling. In a recent comprehensive review on evacuation modeling, Murray-Tuite and Wholshon (2013) pointed out the importance of interdisciplinary effort among social scientists, transportation engineers as well as those in other disaster-relevant fields towards better planning and modeling. Also the importance of considering specific hazard type in modeling was pointed out.

To this background, and aimed towards the endeavor of bringing together professionals from different fields involved in disaster management, this paper reviews a broad range of factors that determine evacuation decision from the point of view of evacuation managers and

social scientists as well as engineers particularly, transportation planners. The complex factors identified are scrutinized according to the definitions of disaster management concepts including risk assessment, risk information, risk communication, risk awareness and risk perception. From here, the complex factors are grouped into individual/household socio-demographic characteristics, capacity-related and risk-related factors. The implications of these factors to evacuation planning and modeling specifically in the context of flood are indicated. Future research includes further analysis of the interrelationships of complex factors towards more simple evacuation modeling. Before implemented in practice, research needs to prove that integration of the factors from the viewpoint of evacuation managers and social scientists as well as transportation engineers, could contribute to better understanding of what is really happening during emergencies, hence better evacuation planning and modeling.

## 2. FACTORS THAT DETERMINE EVACUATION DECISION

There are four broad concepts reviewed in this section: the household characteristics, risk-related concepts, capacity-related concepts and evacuation planning. The interrelationship of these concepts is based on recent research efforts in the area of social sciences, risk analysis and evacuation planning and modeling. These concepts and specific components are discussed in the succeeding sections.

### 2.1 Risk-Related Factors

Risk has been viewed by researchers as a social concept of interpreting danger which takes into account specific setting and culture, while others describe it by its social meaning with characteristics of worry, dread, anger, anxiety (Dash and Gladwin 2007). However, the risk that people face, according to its definition as a disaster management concept is the interaction of hazard and the vulnerability (Ren, 1998). Hazard is normally characterized by its frequency and severity (Cadag and Gaillard, 2012). While vulnerability could be seen in two dimensions, that is sensitivity and response capacity (Lebel *et al*., 2011). From here, it could be argued that the vulnerability is related to the socio-demographic characteristics of household. However, further research is needed in identifying which specific factors could explain evacuation decision.

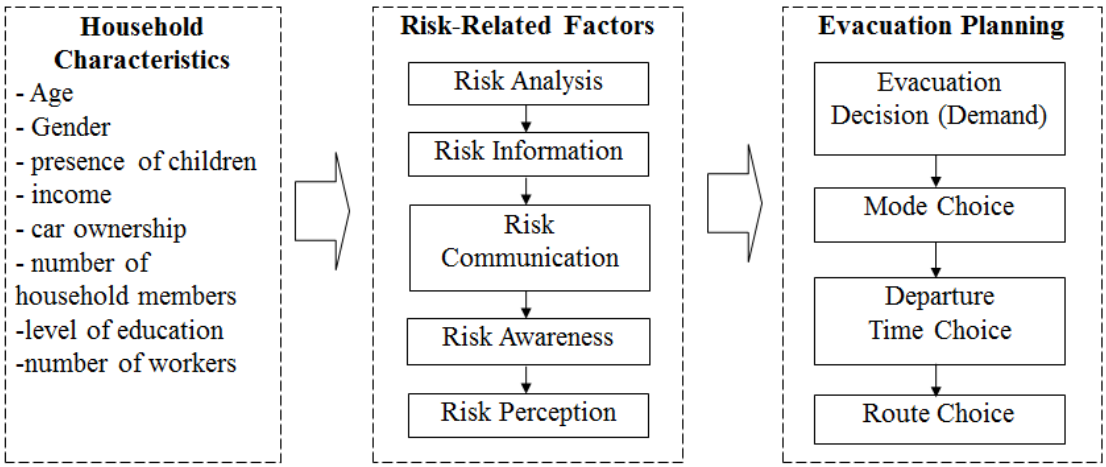


Figure 2. Relationship of risk-related factors, evacuation decision and evacuation planning

Building on these concepts, this section attempts to bring about how risk-related concepts (Figure 2): from risk analysis, translated to risk information, to communicating this information (warning) and how this information builds the risk awareness of people, which boils down to risk perception, eventually affects evacuation decision and evacuation planning. By reviewing the literatures, specific factors that could be adapted in evacuation planning process are suggested.

### 2.1.1 Socio-demographic characteristics

As mentioned above, the vulnerability factors could be related to socio-demographic factors. Lebel *et al*. (2011) defines vulnerability as "the susceptibility of adverse impact or harm arising from flood event" and further mentioned its two dimensions including sensitivity and response capacity. Sensitivity is a measure of degree to which a system is affected by a disturbance. While response capacity could be viewed as short term (coping capacities) and long-term (adaptive capacities) views. The impacts experienced depend on vulnerability of the system and the exposure, or the duration and degree of contact with the hazard such as flood. Vulnerability is shaped by the social and ecological circumstances of everyday living in general and flood and disaster management practices, specifically. From here, it could be argued that the vulnerability is related to the socio-demographic characteristics of individuals/household. However, further research is needed in identifying which specific factors could explain evacuation decision.

Factors such as age of the decision maker, presence of children or elderly in the household, gender, disability, race and ethnicity, and income have seen to affect evacuation decision (Dash and Gladwin, 2007). However, the effects and interrelationships of these factors depend on the level of risk and severity of potential risk impact. Findings in research which analyzed the effects of socio-demographic and economic characteristics of individuals/household to evacuation decision show varied effects between insignificant and significant (Murray-Tuite and Wolshon, 2013). This shows that effects of these factors to evacuation decision are not yet well understood and therefore needs to be further studied. Specifically, the effects of these factors in relation to specific hazard, in this case, flooding, should be further investigated.

### 2.1.2 Risk analysis

Risk analysis is defined as the "assessment of the probability of a particular hazard to affect a vulnerable area, population, among others, that could result to disruption of its original functioning" (Abarquez, 2004). The process of risk analysis involves the identification and assessment of the hazard and vulnerability, which is translated to hazard maps that represent a clear picture of the risk and who are at risk (Cadag and Gaillard, 2012). In the case of flood, the prediction of inundation level, illustrated in the risk maps is the basis for emergency planning where measures are undertaken such as preparing for warning messages, undertaking mitigation measures such as blocking flood passageways with sandbags, scouting for and preparing shelters, and evacuating people before getting stuck (Piatyszek and Karagiannis, 2012). In another matter, knowledge of the location of the people at risk also contributes to better understanding of evacuation decision. It has been shown in research that individuals/households situated at high flood risk zones are likely to evacuate. While others situated at low risk level zones are likely to evacuate voluntarily (Siebeneck and Cova, 2012).

### 2.1.3 Risk information

The result of risk analysis is transformed from risk maps into relevant information that is useful in the field known as flood risk information. This information is often presented in emergency plans with corresponding actions listed based on the estimated level of risk. In order to encourage evacuation compliance, information on hazard and its potential impact should be translated into solid information of the pending hazard (Dash and Gladwin, 2007). In addition, understanding the risk levels of the area gives rise to comprehensive emergency planning. People take action when knowing and understanding the risk level (Piatyszek and Karagiannis, 2012).

### 2.1.4 Risk communication

After the generation of risk information, communicating it to the individuals/household at risk plays a significant role in understanding evacuation decision. Risk communication is a process concerning interaction over time between the source and receivers (Fessenden-Raden, 1987). The risk communication, referred to as warning in evacuation planning could be general and specific. The latter is considered when evacuation instruction is issued once a hazard is detected to potentially hit a vulnerable area at a given time (EMA, 2005). After hearing warnings and people believed the message, then, likely response is to evacuate (Dash and Gladwin, 2007). However, people of various characteristics, process information and respond differently to warnings they have received. Hence, it has been suggested that warnings should be crafted according to how people respond for better compliance on evacuation (e.g. Fessenden *et al.*, 1987; Kievik and Guttelling, 2011). Elements of warning that needs to be taken into account and have been implemented in practice (e.g. EMA, 2005) include the source of information, the detailed information regarding hazard characteristics, risk, mediums of information, the receiver and feedback. In the case of businesses, warnings issued by authorities with long lead times contribute to effective implementation of measures (Kreibich *et al.*, 2011). Specifically, more individuals/households and businesses know better what actions to take when they received warning of impending flooding.

An area for further research in risk communication has been suggested such as the effect of news media and social media to the decision of evacuees (Siebeneck and Cova, 2012).

### 2.1.5 Risk awareness

Risk awareness results from the warning received by individuals/households. The level of this awareness in relation to evacuation decision depends on how effective the warning is communicated (Kievik and Guttelling, 2011). Additionally, risk awareness and flood experience is found to be related. Risk awareness is higher for people who had previous experience and lower to those without (Scolobig *et al.*, 2012). Also, when an individual is informed of the risk, two cognitive processes is activated including the assessment of threat and coping with the situation (Koerth *et al.*, 2012). This implies the interrelationships among risk information, communication and awareness, which in turn affect evacuation decision. Understanding of the factors that affect risk awareness and their rippling effect to evacuation decision is one research endeavor.

### 2.1.6 Risk perception

Risk perception is key to understanding the evacuation decision-making process (Dash and Gladwin, 2007; Terpstra *et al.*, 2009). The way people perceive risk is a result of all information and knowledge from the process described in the previous sections above. It is

complicated from the analysis of the risk itself until how warnings are communicated, with several factors to be considered under each of these. As a result, decision makers have to make choices from a range available to them according to the information they get, their situation and a wide range of other external factors (Dash and Gladwin, 2007).

It has been found in research that risk perception affects evacuation compliance with protective orders. The higher the level of risk perception, the more likely that people decides to evacuate (Siebeneck and Cova, 2012). However, risk perception has been studied mainly in the areas of social and behavioral sciences as well as in emergency management studies (e.g. Slovic *et al.*, 1982; Terpstra *et al*., 2009; Siebeneck and Cova, 2012). In addition, the way risk perception is measured, differs from one study to another. For instance, risk perception is interpreted by individuals/households as a choice from pre-determined measures like "risky" and "not risky" (Simonovic and Ahmad, 2005). In other considerations, risk perception is associated with environmental cues and hazard-related factors according to past evacuation experience (Siebeneck and Cova, 2012). While the factors that have been considered in these studies are significant to understanding risk perception, integrating the factors such as those mentioned in the previous subsections above is missed in research. For instance, the effect of risk communication to people's perception of risk is not clearly defined in research (e.g. Terpstra *et al.,* 2009). This issue, therefore, is important to be more understood in research and is further presented and discussed in relation to evacuation modeling in section 3 of this paper.

## 2.2 Capacity-Related Factors

Capacity is defined as the "ability of the community to deal with hazards" (Abarquez, 2004). The relationships of factors including income and social capital, preparedness and ability to adapt to disasters is reviewed and analyzed in connection to evacuation planning (Figure 3).

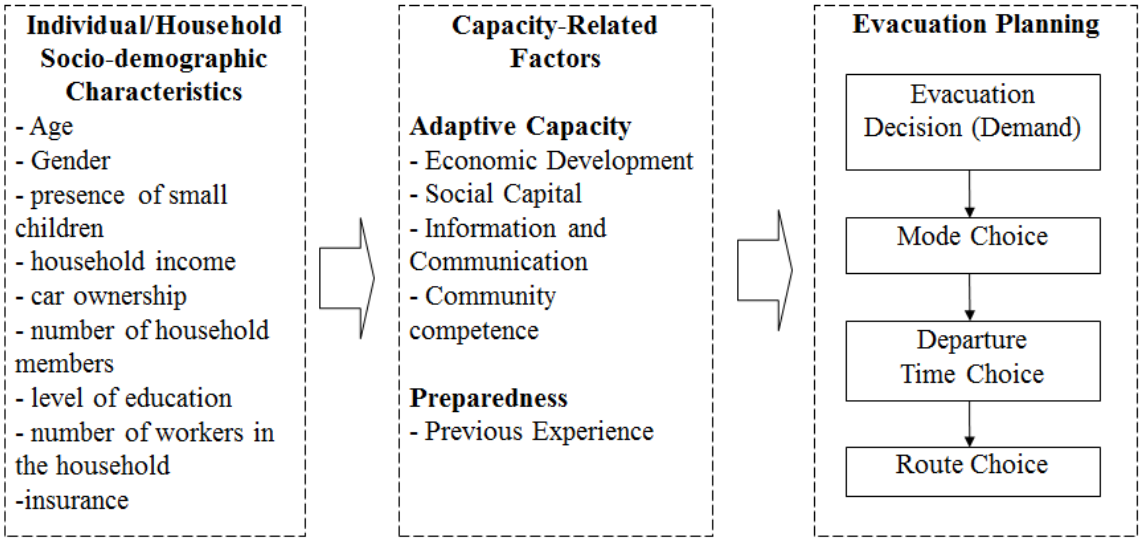


Figure 3. Relationship of capacity-based factors, evacuation decision and evacuation planning

### 2.2.1 Socio-demographic characteristics

As mentioned in the previous section 2.1.1, factors such as age of the decision maker, presence of children or elderly in the household, gender, disability, race and ethnicity, and income have seen to affect evacuation decision. Based on Figure 3 above, specific socio-demographic factors that are related to the adaptive capacity is an obvious point of

analyzing its relationship to evacuation decision. For instance, the income level of the household, the number of workers in the household as well as the presence of insurance could be related to economic development under the adaptive capacities. Also, the presence of social capital such as relatives and business partners could be related to the adaptive capacity as well.

### 2.2.2 Adaptive capacity

Adaptive capacities that describe resources with dynamic attributes link the community resilience and the adaptation after a disaster (Norris *et al.*, 2008). Community resilience arises from four primary sets of adaptive capacities that determine an approach for disaster preparedness. These adaptive capacities include economic development, social capital, information and communication, and community competence. Further, some factors that build any of these adaptive capacity includes encouraging participatory planning, involving people in mitigation measures, creating organizational links for better risk information exchanges, advancing and protecting social supports and improving decision-making abilities (Norris *et al*., 2008). The effects of these factors have been somehow touched in many literatures cited herein. However, the collective effect of adaptive capacities has not been studied by far. An adaptive index that could serve as indication for evacuation decision would be an area of research.

### 2.2.3 Preparedness

Preparedness is described as the ability of the community to avoid the negative impacts of an impending hazard (Abarquez, 2004). Factors that affect preparedness are for instance risk awareness and flood experience, which are interrelated. It is argued in research that the main cause of low preparedness is low risk awareness which is further related to poor evacuation compliance (Scolobig, *et al.*, 2012). Experience connects preparedness and risk awareness and personal experience explains household adaptive behavior (Koerth *et al.*, 2012).

Recent studies show that flood experience results to significant reduction in damage and/or losses because of increased level of preparedness and mitigation measures (Kriebich and Thiecken, 2009; Xiao *et al.*, 2011). In addition, warning, is also related to preparedness in that the more lead time provided in a warning, the higher is the level of preparedness as well as protective measure of people at risk (Sullivan and Häkkinen, 2011; Krebich *et al.*, 2011).

In disaster management, preparedness is presented as collected measures to avert the impacts of disaster, and evacuation is one of these measures. With this, it could then be argued that collective preparedness measures could affect evacuation decision. Therefore, future studies could focus on the effects of the level of preparedness and its integration to other factors in estimating the likelihood of evacuation decision. In doing so, a preparedness index could be developed in research (e.g. Orencio and Fujii, 2012). Then, this index could be one of the factors to be analyzed in relation to evacuation decision.

## 3. EVACUATION DECISION AND EVACUATION DEMAND MODELING

Evacuation models describe the decisions of travellers regarding evacuation participation and departure time (Pel et al., 2012). These are subsequent models that include evacuation decision, evacuation route decision as well as evacuation mode choice decision. The evacuation decision is the base of building the subsequent models of route and mode choice.

Mode choice model is used to predict the proportion of the vehicles to be loaded to the network from each origin based on schedules of movement. The route choice model determines how the vehicles are distributed to the each identified routes. Since the outcome of evacuation decision is the most important element serving as an input to evacuation planning, incorporating behavioral aspects into the evacuation operations is necessary. Understanding and knowing these outcomes result to better planning and allocation of resources.

Many studies in the field of social and behavioral sciences, specifically in the area of disasters and management focus on the analysis of the reality in the outset of disasters. Capturing these complex behaviors involved given environmental and social elements are necessary for better planning and effective implementation of evacuation. To this background/view, efforts in evacuation transportation planning and modeling are done in research. Many studies in the field of social and behavioral sciences, specifically in the area of disasters and management focus on the analysis of the reality in the outset of disasters. Capturing these complex behaviors involved given environmental and social elements are necessary for better planning and effective implementation of evacuation. Travel demand then helps identify the number of vehicles to be used for moving people, as well as the best possible routes for moving these people minimum time possible (Hsu and Peeta, 2012). People who chose not to evacuate and will do voluntarily should also be considered in traffic flow. To this background/view, efforts in evacuation transportation planning and modeling are done in research.

Evacuation decision models that have been proposed in research as well as the factors identified to be significant, grouped into socio-demographic characteristics, capacity-related and risk-related are presented in Table 1. Whitehead *et al.* (2001) in their study on evacuation decision found groups of factors including socio-demographic characteristics and risk-related factors of hurricane to be significant to the decision. Fu and Wilmot (2004) proposed a dynamic travel demand model which is a simultaneous model of evacuation decision with significant factors including socio-demographic characteristics and risk-related factors. Stopher *et al.* (2004), who proposed models for evacuation decision in the case of bushfire, identified factors that including also socio-demographic characteristics and risk-related factors. Charnkol and Tanaboriboon (2006) investigated evacuation decision of two people groups, the permanent and transient residents in Thailand in case of tsunami and found significant factors including socio-demographic characteristics, capacity-related, and risk-related factors. Fu *et al.* (2006) estimated the same model that was estimated in Fu and Wilmot (2004) and added more risk-specific factors to the model. Hasan *et al.* (2011) have identified factors including the three group of factors. Although these research efforts have contributed towards consideration of behavioral aspect in evacuation modeling, the models are focused mostly on hurricanes. Moreover, the findings in relation to the three broad groups of factors vary from one model to another in addition to the complex factors within each group. Moreover, the interrelationships of these factors are not considered in the studies. In addition to these research efforts in understanding evacuation behavior for incorporation to evacuation models, very recent studies such as that of Fang and Edara (2013), Li *et al*. (2013) and (Gudishala *et al.*, 2013) are promising. However, these studies also focus on hurricane. Efforts have been very limited in the case of flood.

Table 2 shows the evolution of flood evacuation decision models and studies that have considered behavioral analysis in determining the factors that affect the decision. The table indicates that not many studies have been done in the area of flood evacuation. Studies done between 1968 and early 1990s focused on analyzing the effects of factors such as perceived risk, warning content, warning confirmation, source credibility, possession of an adaptive plan, social network contacts and previous and/or frequency of flood experience. Findings from

these studies vary from evident significance to unclear effects which indicate further studies needed to have a definite conclusion on which factors affects flood evacuation decision. Later studies are significant efforts towards better understanding of complex factors.

Table 1. Evacuation decision models and significant factors

| Author | Hazard Considered | Significant Factors | | |
|---|---|---|---|---|
| | | Socio-demographic characteristics | Capacity-related | Risk-related |
| Whitehead *et al.* (2001) | Hurricane | income, race, sex, education, housing type, pet holders, presence of young children, presence of elderly children | x | hurricane characteristics, perceived risk |
| Fu and Wilmot (2004) | Hurricane | housing type | x | distance to the storm, the forward speed of the hurricane, time-of-day, presence of an evacuation order, possibility of flooding, |
| Stopher *et al.* (2004) | Bushfires | age, gender, presence of younger children, presence of old age adults, length of stay in residence, number of vehicles | x | temperature, wind speed, wind direction, fire type, fire distance |
| Charnkol and Tanaboriboon (2006) | Tsunami | number of household members, marital status, level of education | disaster knowledge, past experience, presence of ship/vessel | distance to nearest shore |
| Fu *et al.* (2006) | Hurricane | housing type | x | the distance to the storm, the forward speed of the hurricane, time of day, presence of an evacuation order, possibility of flooding, hurricane wind speed, time-to-landfall |
| Hasan et al. (2011) | Hurricane | work during evacuation, number of children, house ownership status, type of housing (mobile), income and level of education | previous hurricane experience | Geographic location, source of notice for evacuation, type of evacuation notice received |

One of the most comprehensive, if not the only flood evacuation model which considered a wide range of factors is that of Simonovic and Ahmad (2005). In this study, computerized simulation evacuation model was developed including an evacuation decision model. Four broad groups of factors including social factors, internal factors, initial factors and psychological factors, as well as policy variables were analyzed for inclusion in the evacuation decision model. Social and internal factors were explained by the socio-demographic characteristics of individuals/households such as income, age group, and daily life pattern, past flood experience, risk awareness and knowledge about disasters. Policy factors include flood warnings and evacuation order. Psychological factors include concern, recognition and acceptance of risk, and evacuation decision. Risk recognition was analyzed using social factors such as age, presence of dependents in the family (children or elders) in combination with external factors such as heavy rain and flood conditions. Although the simulation model proposed provides a useful evacuation decision model, its limitation is that it is only based on "what if" scenarios (Xie *et al.,* 2010). In addition, further research is recommended for careful analysis on a number of exogenous variables that might actually be

endogenous variables.

Table 2. Summary of studies on flood evacuation decision with behavioral considerations

| Factors considered | Consideration in risk related factors for evacuation decision | Recommendations for future research | Author |
|---|---|---|---|
| Frequent hazard experience | Frequent experience influence compliance | Study relationship to adaptive capacity | Anderson (1968) |
| Previous or recent hazard experience | Past experience influence behavior | Improve risk communication through education and raising awareness | Gruntfest (1977) |
| Receive warning from authorities, belief of real situational danger/risk perception | Warning from authorities are most believed and factors of compliance | Relationship with risk perception and other factors | Perry (1981) |
| Social network contacts, warning from authorities, belief that real danger existed | Warning from authorities are most believed and factors of compliance | Effects of mixed information | Perry (1983) |
| Social network | Believe information and decision of network | Study other factors | Anderson *et. al.* (1984) |
| perceived risk, warning content, warning confirmation, source credibility, possession of an adaptive plan. All are correlated to the decision making | Perceived risk best explains evacuation decision; ethnicity is insignificant factor | Result of insignificance of ethnicity should be further investigated | Perry and Lindell (1991) |
| Subculture: cultural patterns,<br>Social factors, internal factors, initial factors and psychological factors, policy variables | Range of included factors influence decision | Examine interrelationships of exogenous and endogenous variables | Simonovic and Ahmad (2005) |
| Risk information | Traveler information affects evacuation decision | Impacts of changing information to decision | Pel *et. al*. (2010) |
| Risk perception | Risk perception and evacuation decision is influenced by spatial and temporal characteristics of risk | Examine interrelationships between hazards, risk perception and risk communication throughout the evacuation process | Siebeneck and Cova (2012) |

Pel et al. (2010) proposed a model of integrating traveler information and compliance behavior in EVAQ. The focus lies on predicting travellers' decisions to evacuate, choice of departure time, destination and route. For the evacuation participation and departure time choice, simultaneous approach to dynamic evacuation demand prediction using the repeated binary logit model is considered. Here, analysis of the evacuation compliance was done by only focusing on the departure time choice, which shows no consideration of further complex behavioral elements of the decision making process. Although study result shows the need to incorporate traveler information and compliance into evacuation models, future research is needed to understand the impacts of changing information and evacuation decision results, which clearly is related to many behavioral aspects.

The research efforts discussed in this section have contributed towards considering behavioral aspect in evacuation modeling. However, they have one thing in common. The

complex behavior that is associated with evacuation decision is not well-captured. The interrelationships of the complex factors have not been explored. Therefore, further research is suggested in the area of behavioral evacuation decision making.

## 4. SUMMARY AND CONCLUSION

Evacuation decision is a key part for evacuation planning and modeling. Careful examination of the factors that could determine evacuation decisions of many people with complex decision characteristics should be done in research. In addition, these factors should be investigated specific to the type and nature of disaster (Murray-Tuite and Wholshon, 2013). This is primarily because hazards have their specific attributes and its extent and level of impacts vary. Moreover, the perception of people towards different hazard and their associated risk varies widely. People's perception of risk varies depending on how they assess the risk, how they understand risk information, how the risk were communicated, how high is their level of awareness on their risk, and eventually how high is their level of perception to the risk.

This paper reviews a broad range of factors that determine evacuation decision from the point of view of evacuation managers and social scientists as well as transportation planners. In view of identifying factors relevant to evacuation decision, concepts related to risk (such as risk analysis, risk information, risk communication, and risk perception) and capacity (such as adaptive capacity and preparedness) are reviewed. Then, the factors related to these concepts and have been identified in research as significant factors to evacuation decision are put to light. In order to analyze evacuation decision in a complex behavioral manner, risk perception, should be explained by a cluster of factors that include socio-demographic, capacity-related and risk-related factors. These broad categories of factors, according to the review of the definition of disaster management concepts are interrelated in a manner as presented in Figure 4. In addition, the relationship of these factors to evacuation decision, and ultimately to evacuation planning is as indicated.

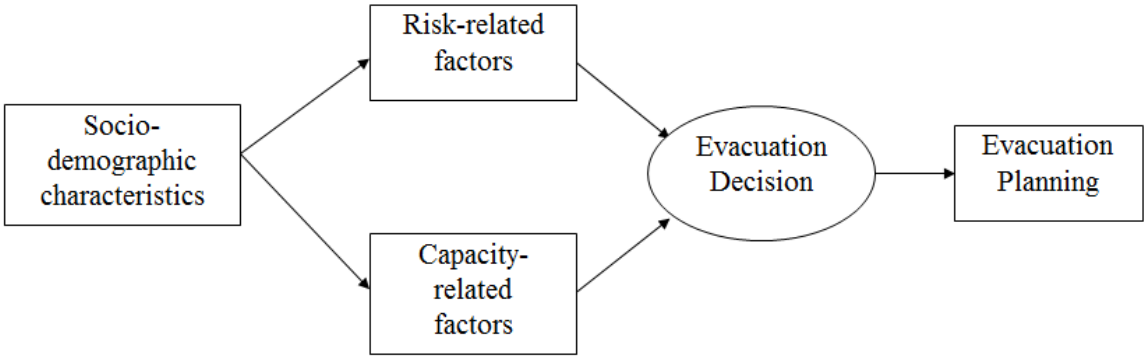


Figure 4. Relationship of individual/household characteristics, risk and capacity-related factors to evacuation planning

Factors influencing evacuation decision that were used in models vary in different studies. Fu and Wilmot (2004) who developed model for hurricane with two decision options including evacuate/stay, identified distance to storm at time t; time-of-day, forward speed at time t, presence of an evacuation order, possibility of flooding. Stopher *et al.* (2004) who proposed models for evacuation decision in the case of bushfire with three decision options of

total household evacuation, partial household evacuation and no evacuation included in the factors of socio-demographic characteristics (age and gender of decision maker, number of vehicles, presence of younger children, presence of old age adults, length of stay in residence) and risk-related factors (wind speed, wind direction, fire type, fire distance). Simonovic and Ahmad (2005) considered four broad groups of factors including social and internal factors (income, age group, and daily life pattern, past flood experience, risk awareness and knowledge about disasters), policy factors (flood warnings and evacuation order), initial factors and psychological factors (concern, recognition and acceptance of risk, and evacuation decision). Fu *et al.* (2006) estimated the same model that was estimated in Fu and Wilmot (2004) and added hazard-specific factors hurricane wind speed and time-to-landfall. Charnkol and Tanaboriboon (2006) included factors including member, distance, experience, knowledge, presence of ship/vessel, children, occupation, marital status, education, age. Hasan *et al.* (2011) have identified factors including geographic location, source of notice for evacuation, work during evacuation, number of children, house ownership status, type of housing (mobile), type of evacuation notice received, previous hurricane experience, income and level of education.

Although the research efforts in evacuation decision as reviewed in this study have contributed towards considering behavioral aspect in evacuation planning, they have one thing in common. The interactions of complex factors including socio-demographic characteristics of the decision maker, capacity-related and risk-related factors are not well-captured. Assessing interrelationship among these many factors could influence better identification for inclusion in modeling evacuation decision, thereby assisting in better evacuation demand modeling.

In doing so, several methods and tools could be used to evaluate the effects of these factors and their interrelationships such as probit and other similar approaches. Additionally, Murray-Tuite and Wholson (2013) mentioned that nested logit has not been used as a discrete choice model for choices on evacuation typology. Other discrete choice models could also be explored as a method in evaluating the factors mentioned above such as continuous cross-nested logit (Lemp *et al.* (2010) as evacuation involves continuous variables such as location, departure time, activity duration and vehicle usage.

In addition, the applicability of methods used in developed models specific to hurricane, a well-studied type of hazard, is one area for furthering research for flood evacuation modeling. One example is that of Li *et al.* (2013) where evacuation behavior is analyzed through construction of the evacuation response curve based on traffic data collected during Hurricane Irene. The S-curves with different mathematical functions and state-of-art behavior models calibrated and compared with empirical data, indicates good fit. Another example is that by Gudishala *et al.* (2013), where predictive accuracy of time-dependent sequential logit evacuation demand model was examined. The results of the empirical analysis suggest that a disaggregate evacuation demand model can be used to predict future evacuation behavior with reasonable levels of accuracy.

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