

Research Article

Studying the Role of Personality Traits on the Evacuation Choice Behavior Pattern in Urban Road Network in Different Severity Scales of Natural Disaster

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The study of evacuation behavior in response to disaster is necessary for emergency traffic management. As decision-making is not exclusively dependent on observable variables, in this research, it is attempted to study the evacuation choice behavior pattern in emergency response to earthquake disaster by considering both physical and behavioral factors. Personality traits are measured as behavioral latent factors by confirmatory factor analysis (CFA) of the short form of NEO-Five-Factor Inventory (NEO-FFI). A revealed preference survey with more than 700 samples was conducted in Qazvin city (Iran) which was based on real-life earthquake experience and the stated preference survey was conducted for six designated scenarios with different severities and times of earthquakes. Analysis of evacuation behavior is conducted by 3 types of discrete choice models (traditional binary logit model (TBLM), hybrid binary logit model (HBLM), and random parameters/mixed binary logit model (MBLM)). First, TBLM is estimated to study the effect of observable variables on response of people to earthquake disaster. Then, by adding the personality traits to modeling structure and constructing HBLM, the correct prediction percentage of the model increased. This study also considers heterogeneous mixtures of population in terms of income, family size, and five factors of personality traits by MBLM. The MBLM captures the heterogeneous responses of the respondent. By considering these variables as random parameters, the Log Likelihood function and pseudo square (ρ^2) of the model increased.

1. Introduction

An earthquake can be a catastrophic incident that kills thousands of people due to the lack of preparedness for confronting to it. Iran is always in danger of earthquake disasters due to its seismic belt. Iran's earthquake-related mortality rate is about 6% of the world compared to its population, which is only 1% of the world [1]. In countries such as Iran, the experiences of natural hazards indicate that management before an earthquake is very important. The importance of evacuation studies in the aftermath of a disaster is recognized by researchers of natural hazards [2, 3]. The prediction of the evacuation choice in the aftermath of an earthquake is challenging due to the uncertainties on the level of damage and decisions by individuals. Decisions are

influenced by the behavior of households and should be formulated probabilistically [4]. Modeling the evacuation choice behavior is challenging and the complexity of behavioral factors identification adds dimensionality to the problem of evacuation planning. Ignoring this component in evacuation planning may lead to inaccurate estimation of the demand for evacuation [2]. After the earthquake, abnormal traffic demand for unspecified purposes will lead to major traffic problems throughout the transportation network [5]. Post-earthquake travel demand could be substantially altered because of travellers' reaction to earthquake risk perception [6]. Human behavior is difficult to predict at all times and even more during emergencies, which are stressful and chaotic events. In this regard, it is necessary to study the behavior of people in the transport network in the event of an

earthquake disaster in order to predict the expected situation. The question of how people act during an earthquake is complex and the answers are inconclusive [7]. Currently, there is no unified recommendation regarding appropriate behavior when an earthquake occurred [8]. It has been noted that an individual's affective reaction to an environmental change can impact their behavioral intention. In order to predict the post-earthquake transport network situations, it is first necessary to examine how people behave in earthquake-prone situations. Therefore, it is important to understand what behavioral factors can influence people's decision to evacuate after an earthquake. Several researches have studied people's response to natural hazards [9–11] but few of them considered the effect of personality traits on responses to potential disasters. The main objective of this research is to study the effect of personality traits on evacuation choice in response to an earthquake disaster in different severities and times of earthquake. The required information in this study was collected through a revealed preference survey about earthquake that occurred on December 20, 2017 and a stated preference survey designed for earthquake scenarios at different times and severities. As the effect of personality traits on people's response to an earthquake is not considered in previous studies, in this research effects of personality traits as latent variables on evacuation behavior have been investigated. For this reason, first TBLM with observed variables is estimated. Then, to identify the effect of personality traits on evacuation choice behavior in response to earthquake disaster, HBLM with observed and latent variables are estimated. Finally, as income, family size, and five factors of personality traits are random variables and these random characteristics become more obvious during an earthquake because of an unexpected situation, the MBLM is estimated to capture the heterogeneous responses of respondents. The information obtained from this study can be used in post-crisis planning.

2. Literature Review

Many researchers surveyed the factors affecting decision-making of individuals on the occurrence of disasters and provided different behavioral models in this regard. In this section, in order to identify the factors that influence the action choice in response to disasters, a comprehensive review of previous studies is done.

Whitehead et al. investigated evacuation behavior in the occurrence of hurricanes. They indicate that socioeconomic characteristics affect how people respond to disaster by estimating logit model [9]. Horikiri and Odani investigated the behavior of the individuals after an earthquake. In their research, the number of family members was identified as influencing factors in evacuation behavior [10]. In the study of Bateman and Edwards, results show that women are more likely to evacuate than men because they feel more at risk or feel more responsible to protect children [11]. In a research by Walton and Lamb, travel behavior after the earthquake was studied using designated stated preference (SP) scenarios. The results of this research indicate that factors such as trip destination, estimated distance, and trip mode are factors affecting

trip choice behavior [12]. Solís et al. determined the individuals' choice behavior in the event of a Hurricane using probit modeling [13]. Eiser et al. proposed a general framework to assess the response to natural disasters. In their opinion, the perceived risk of disasters that affects the response of an individual depends on factors such as following previous experiences, values, individual feelings, cultural beliefs, and social variables [14]. Yun and Hamada investigated evacuation behavior during the 2011 Tohoku-Oki Earthquake. Results indicate evacuation starting time, age, and occupation had the greatest influence on evacuation [15]. In the study by Yang et al. the factors affecting evacuation behavior was investigated. In this research, structural equation models were used to estimate the choice behavior of individuals. It was found that age and education levels affect the evacuation decision [16]. Shapira et al. investigated the anticipated behavior patterns of residents in a high seismic risk area in Israel in the face of an earthquake scenario. Level of earthquake preparedness and dwelling type are significant predictors of behavioral strategy choice [7]. In the study of Sugiura et al., psychological processes and personality factors for an appropriate tsunami evacuation are investigated by logistic regression analyses. In this study, NEO-FFI inventory is used to analyse the effects of relevant personality traits on voluntary tsunami evacuation behavior. Results indicate that extraversion and openness factors had significant positive contributions, while neuroticism had a negative contribution to voluntary tsunami evacuation [17]. Mohajeri and Mirbaha studied decision-making in response to earthquake disaster including evacuation and destination choice behavior to analyse the pattern of choice behavior in transportation network in emergency situations. The results of their study indicate that religious belief decreases the likelihood of evacuation, while following previous experiences, trusting acquired trainings, and following decisions made by others increase the likelihood of evacuation [18]. Table 1 presents the summary of selected literature on choice behavior in disasters.

After reviewing previous researches, it can be concluded that the complexity of the individual's behavioral response to the disaster originates from the complexity of factors affecting hazard cognitions and motivates protective behavior. As behavioral choice is crucial in the study of responses to potential disasters, investigating the results of researches on factors affecting response to disaster indicates that the role of behavioral characteristics including personality traits in response to unpredictable disasters such as earthquake is neglected in previous studies. Therefore, in this study, the role of personality traits is investigated in response to earthquake disaster by HBLM. Finally, as the literature review shows that the effect of taste variation in evacuation choice with a focus on personality traits as latent variables is not taken into account in previous studies, this research identified the taste variation of latent variables by proposing a random coefficient model.

3. Methodology

Individuals' decision-making and response to disaster are considered in four stages [19] (as shown in Figure 1), including (a) the evacuation choice in response to earthquake

TABLE 1: Summary of selected literature on choice behavior in disasters.

Study (year)	Data collection method	Method of analysis	The most important factor affecting choice behavior in disasters
Whitehead (2000)	RP	Logit model	Socioeconomic characteristics including income, education, gender
Horikiri and Odani (2000)	RP	Descriptive analysis	The extent of house destruction, the distance to the earthquake location, number of family members
Bateman and Edwards (2002)	RP	Logit model	Gender, confronting the risk, perception of danger
Walton and Lamb (2009)	SP	Descriptive analysis	Trip destination, estimated distance, trip mode, and motivation
Solis et al. (2010)	RP	Probit model	Having children, having experience of hurricane, home ownership
Richard Eiser et al. (2012)	-	Review study	Following previous experiences, values, individual feelings, cultural beliefs, and social variables
Yi-Yun et al. (2015)	RP	Logit model	Evacuation starting time, evacuation location conditions, age, occupation
Yang et al. (2016)	RP	Structural equation model	Age, education levels, distance to the shore
Shapira et al. (2018)	SP	Multivariate logistic regression	Socioeconomic status, levels of earthquake preparedness, and dwelling type
Sugiura et al. (2019)	RP	Logistic regression analyses	Psychological processes and personality factors
Mohajeri and Mirbaha (2021)	SP	Binary logit Model, Multinomial Logit Model	Religious belief, following previous experiences, trust in acquired trainings, and following decisions made by others

RP refers to Revealed Preference method, SP refers to Stated Preference method.

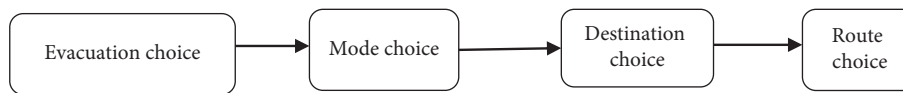


FIGURE 1: Decision-making stages in responding to earthquake disasters [19].

disaster, (b) mode choice (in case of evacuation), (c) destination choice, and (d) route choice. In this study, the issue to be analysed is decision-making in stage one: The evacuation choice in response to earthquake disaster.

In order to analyse and predict the condition of urban road network after earthquake, it is first necessary to examine how individuals behave during an earthquake disaster. For this purpose, the revealed preference survey was used for the earthquake that occurred on December 20, 2017. The earthquake occurred on December 20, 2017, with severity of 5.2 Richter's magnitude scale at 23:27' of Tehran. The focal of this earthquake is reported to be in Malard and its depth was 15 km. This earthquake was also felt in the Qazvin province. In addition, stated preference survey was used for the designated scenarios for the earthquake occurrence in the desired time and severity. Factors affecting the choice behavior under 6 earthquake scenarios (including earthquakes with minor, moderate, and severe severity, and in two time periods of day and night) are studied. In this study, the required data are collected using the designated questionnaire. The data consist of two parts: (1) Observed data including socioeconomic variables and daily trip characteristics, (2) 60-item NEO Five-Factor Inventory (NEO-FFI) data. First, the TBLM using observed variables is estimated and then using the data collected from NEO-FFI, the CFA is estimated in order to find the factor loading coefficients of the latent variables indicators. Then, in order to identify the effect of latent variables (personality traits) on

evacuation choice behavior in response to earthquake disaster, HBLM using observed variables and personality traits are estimated. Finally, to capture the taste variation of individuals, MBLM is estimated and the results of the fit model indices of these models are compared to identify better models. The research structure is presented in Figure 2.

3.1. Case Study. Qazvin is located in the west of Iran with a population of 400,000 and area around and 64.13 km². This city is important due to the presence of powerful seismic faults and active seismic history and the occurrence of earthquakes in the recent years [1]. Figure 3 shows the road network of Qazvin city and the grey area on the map is the worn-out texture of the city.

The data necessary for the seismic hazard analysis were obtained from surveying the type, location, and characteristics of seismic sources, especially faults [21]. Figure 4 indicates the area surveyed for assessing the seismicity comprised a circle with a radius of 150 Kilometers from the city.

In the research of Comijany et al., deterministic Seismic Hazard Analysis (DSHA) is performed to find the worst possible scenario among all the possible seismic sources related to the studied area. The Maximum Credible Design Level (MCL) Contour Map of Qazvin is shown in Figure 5. This level is defined as the strongest ground motion that can reasonably be expected at any structures from a nearby

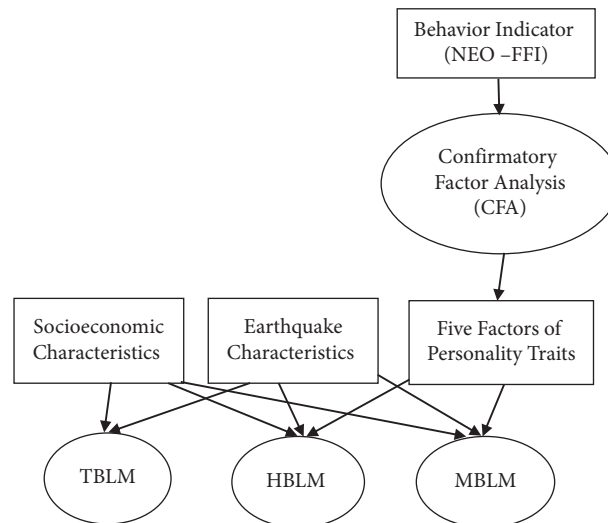


FIGURE 2: Proposed conceptual framework for evacuation choice modeling.

seismic source or on the basis of the seismic history and tectonics of the region [21]. Based on the population density map of Qazvin and data gathered through population census and Qazvin Comprehensive Plan (Figure 6), as the north section of Qazvin city with stronger ground motion has low density of population, devastating impact of earthquakes in all areas of the city is assumed to be the same.

3.2. Data Collection and Questionnaire Designation. A questionnaire is designed to study the factors affecting the choice behavior of the Qazvin city residents in response to earthquake disaster. The designated questionnaire consists of 4 sections:

In Section 1, the socioeconomic characteristics of individuals are surveyed.

In Section 2, the details of individuals' daily trips are surveyed.

In Section 3, the RP data are used as one of the scenarios of the questionnaire. In this research, RP data are used to increase the validity of the collected data, so we needed individuals that have experience about RP scenario. The RP and SP scenarios are presented in one questionnaire and asked simultaneously from the same people. As the majority of Qazvin residents have experience of the earthquake on December 20, 2017, sampling was performed randomly from residents in different regions of Qazvin city and if the person did not experience the earthquake at December 20, 2017 exceptionally, this person was omitted from data base. As having previous experience of earthquake can affect decision-making in response to earthquake disaster, both RP and SP data focused on persons having experience of earthquake on December 20, 2017. In this condition, all respondents are in the same situation for answering the questionnaire.

In Section 4, the designated scenarios are presented. In order to simplify the presentation of scenarios and according to the earthquake background in Qazvin city [21], three categories of minor, moderate, and severe earthquake severities are considered in designing the scenarios. Each individual stated

his/her evacuation choice in response to each severity of the earthquake and each time of earthquake occurrence. Table 2 shows the designated scenarios in the questionnaires in terms of time and the severity of the earthquake.

In Section 5, in order to investigate the psychological factors, personality traits of individuals are considered as qualitative and latent variables. These variables are measured with confirmatory factor analysis. To this end, the abbreviated form of the 60-item NEO-FFI personality questionnaire has been used. The NEO-FFI is a personality inventory that examines a person's Big Five personality traits (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness). The review of the literature focuses on behavioral factors that affect risk perception and evacuation decisions indicates that in the event of natural hazards, NEO-FFI inventory is a reliable tool for representing the psychological factors [17]. It is used to measure personality traits on a 5-point Likert-type scale where 1 means strongly disagree and 5 means strongly agree. Respondents answer 60 statements (12 items per domain). The higher the score on a particular scale, the stronger the intensification of the feature. Neo-FFI questionnaire has good internal consistency, with Cronbach's alpha ranging from 0.68 to 0.86 for five different personality traits which have been observed in previous studies. And, after decades of use, this personality questionnaire has been identified as having validity, reliability, and usability across different cultures [22]. The general structure of the indicators for estimating any latent psychology variable is given in Table 3.

Since it is not possible to investigate the whole society because of time and budget constraints, statistical sample should be analysed. Inadequate numbers of statistical samples cause unreliable results. The Cochran formula is one of the most common methods for calculating sample size [23]. For 381598 statistical population of the Qazvin, with 95% level of confidence, the minimum required sample size according to Cochran formula is 384. In order to increase the validity of the modeling, more than 700 questionnaires were prepared.



FIGURE 3: The road network of Qazvin [20].

For ensuring accurate and appropriate results of data collection, the interviewers were trained and evaluated for correct and uniform data gathering. The validity and reliability of questionnaire is checked by designing pilot questionnaire and conducting a pilot survey (60 people) in order to have a preliminary feedback and make the possible corrections for the main survey. The pilot survey is done by data collection from different regions of Qazvin city and the validity of questionnaire is evaluated by indicators such as α -Cronbach and correlation of collected data between pilot questionnaire and main questionnaire. The results of pilot survey indicate that the designated questionnaire has validity and reliability. α -Cronbach in each structure in the questionnaire is calculated separately and the value of more than

0.7 for this parameter presents acceptable internal consistency of the questionnaire. The abridged form of the questionnaire is presented in Table 4.

The main sampling was performed randomly among residents in different regions of Qazvin city. The respondents were chosen from employees, university students, clients of health centres, customers of gas stations, and businesses in different geographical areas of Qazvin. The required data for this research are provided through 546 questionnaires that were collected and completely answered by inhabitants of Qazvin based on their revealed experience and stated preference for six designated scenarios.

As earthquake is an unpredictable natural disaster, the decision-making in response to it is not only dependent on

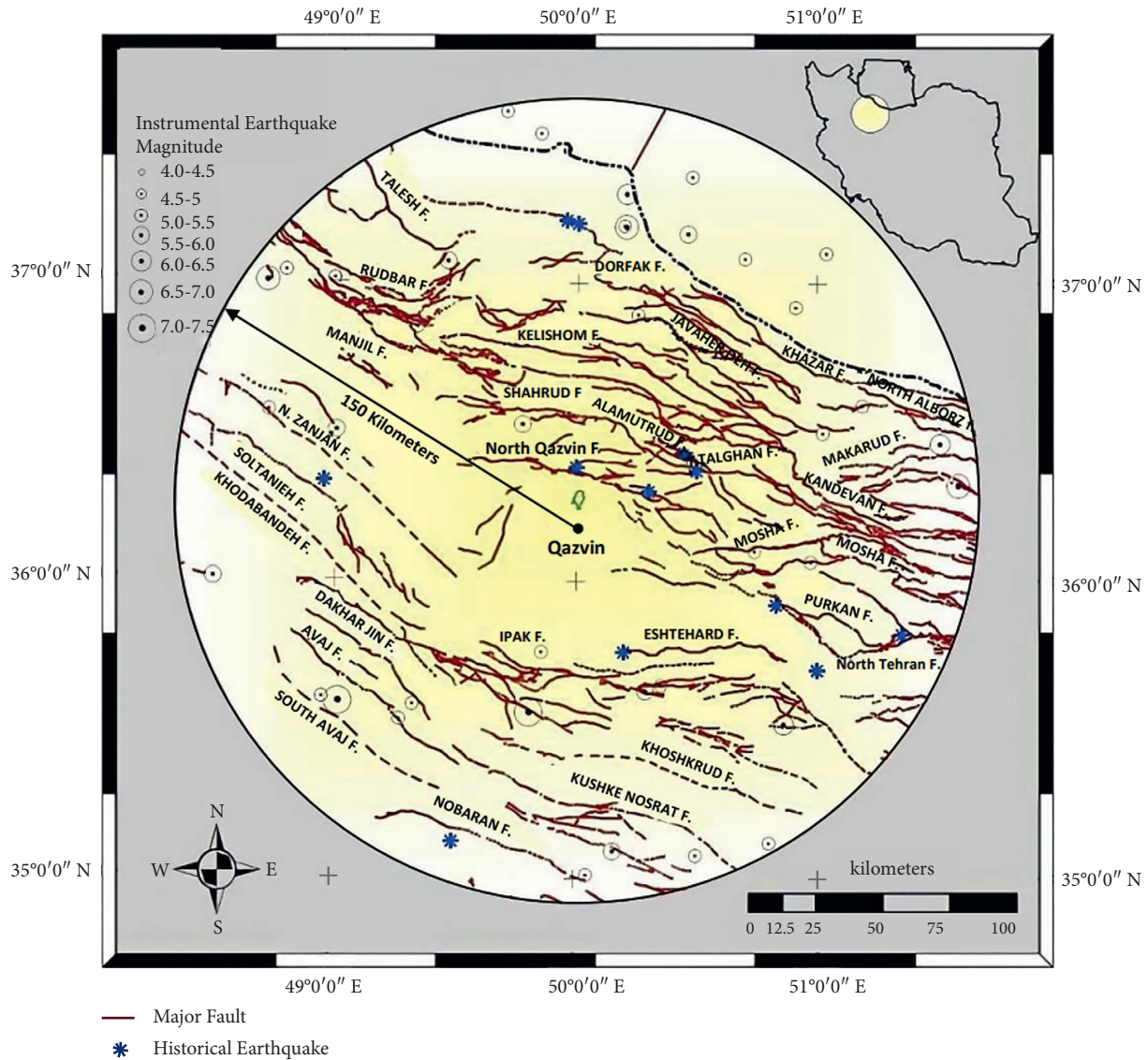


FIGURE 4: Seismotectonic map within a radius of 150 km around the city [21].

observed factors. So in this research, it is attempted to study the pattern of choice behavior in response to earthquake disaster in transportation network by considering physical and behavioral factors simultaneously by estimating hybrid models. The study of simultaneous effect of physical and behavioral characteristics and investigating the role of personality traits as latent variables in response to unpredictable natural disasters such as earthquakes is neglected in previous studies. Another innovation of this research is in terms of designing scenarios, expressing possible scenarios with three severities of earthquake disaster (minor, moderate, and severe) at two times (day, night). Also, simultaneous use of RP and SP data in the data collection method makes this research different from previous researches. Due to the stochastic nature of earthquake occurrence, since the choice behavior in response to the occurrence of earthquake crisis can be completely random, the analysis of data in this study has moved to models with random parameters in the field of personality traits, etc. In previous studies, random

parameters modeling approach for choice behavior in response to earthquake crisis has been neglected.

4. Modeling and Data Analysis

4.1. Modeling Approach. In this study, due to the discrete nature of the dependent variable under study (evacuation or not), discrete modeling was used for analysis. Understanding response to earthquake is used to forecast demand for transportation network and can also be used by emergency planners to improve the infrastructure. There are a number of techniques to understand the response of individuals to natural hazards. The most widely used technique is discrete choice model (DCM). DCM is applicable to evacuation choice modeling as the decision-makers select from a finite set of discrete alternatives. According to the assumption that the alternatives are mutually exclusive and collectively exhaustive, the choice of individuals can be explained by the principle of utility maximization. In this

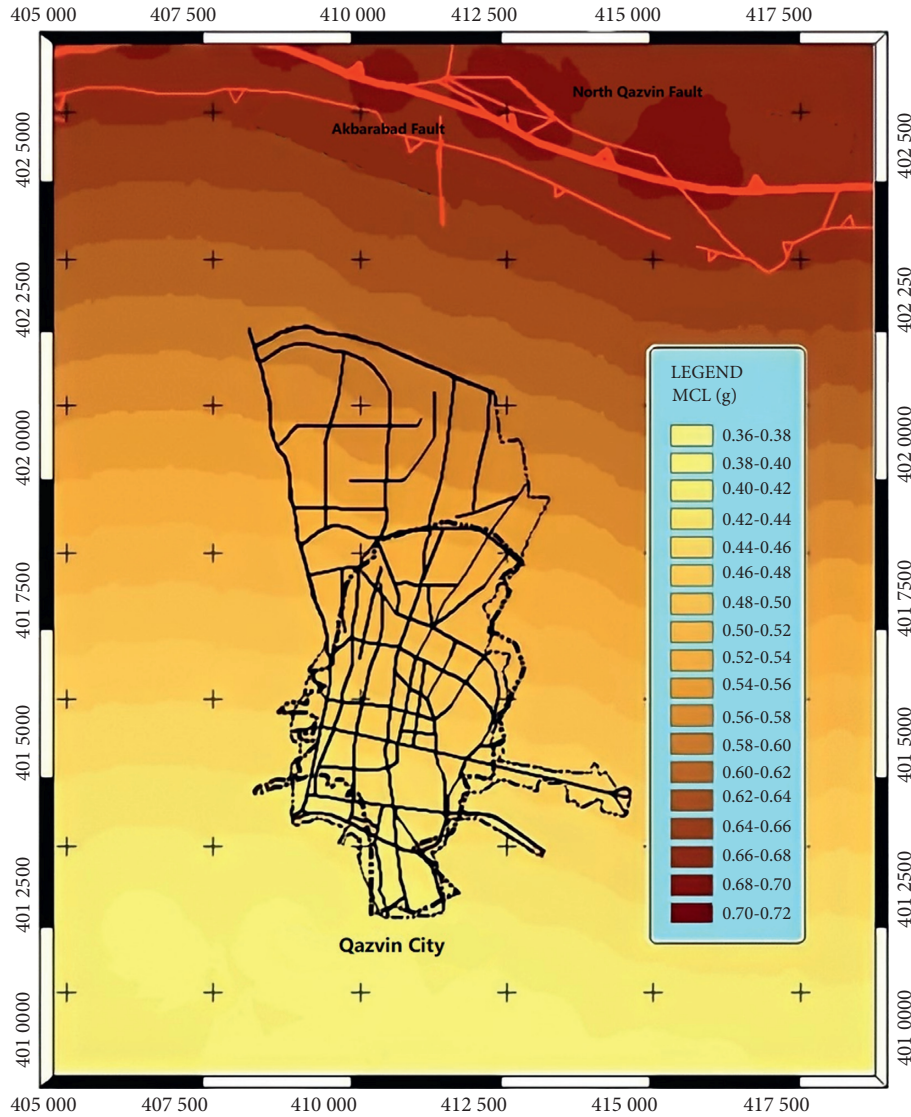


FIGURE 5: MCL Contour Map of Qazvin city [21].

study, first a utility function representing individual preferences for evacuation or not is calibrated to study evacuation choice in response to earthquake disaster.

In the context of discrete choice modeling, the utility function is defined as the sum of a representative component (V_{iq}) and an error term (ε_{iq}), which leads to the following equation [24]:

$$U_{iq} = V_{iq} + \varepsilon_{iq} \quad (1)$$

V_{iq} , considering all attributes that can be quantified by an observer, is usually characterized through measurable properties of the alternatives and the individuals; the error term is considered to take into account all unknown elements affecting the decision. In this regard, if ε_{iq} follows Gumbel distribution, then the probability of occurrence of i for the individual q is $P(i, q)$ by using the traditional logit model which is represented by equation (2) [4].

$$P(i, n) = \frac{e^{T_{in}}}{\sum_{j \in C_n} e^{T_{jn}}} \quad (2)$$

In the traditional logit model, if the dependent variable only has two possible values, such as evacuation/not which is represented by an indicator variable, this model will define as TBLM. Typically, TBLM only considers the measurable attributes of individuals. But over the past two decades, the influence of latent factors during individuals' decision-making process has been taken into account. Recent studies in DCM have emphasized the importance of the psychological factors affecting decision-making. It is also obvious that behavioral factors play a role in the decision-making process, and the usual approach to take these into account considers the estimation of a Multiple Indicator Multiple Cause (MIMIC) model, as suggested by Bollen [25]. In this research, as the evacuation choice is a binary variable, the

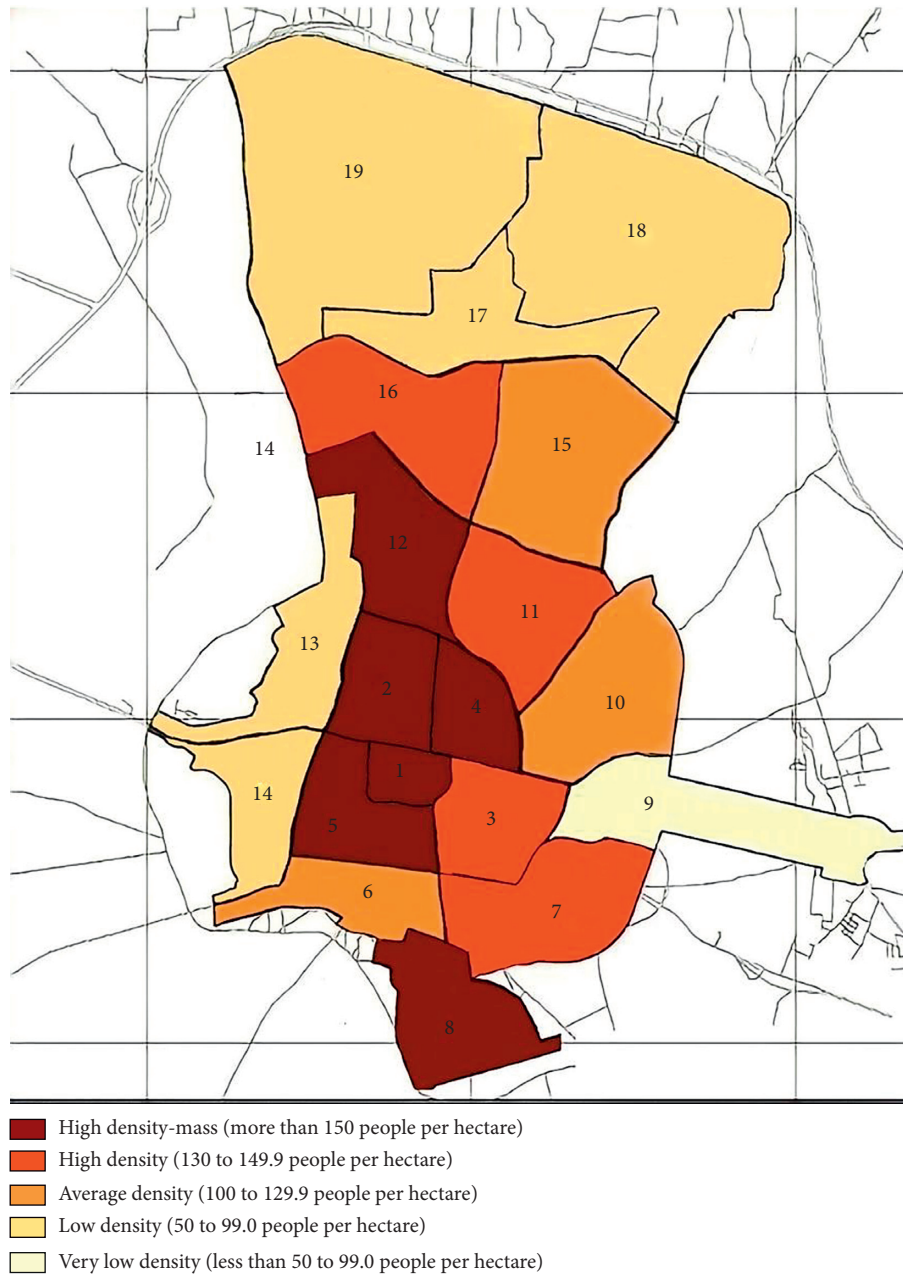


FIGURE 6: Population density map of Qazvin city [21].

joint use of MIMIC models and DCM leads to the hybrid binary choice model (HBLM). The role of the behavioral factors on choice behavior is evaluated by using the Integrated Choice and Latent Variable (ICLV) framework [26].

Hybrid modeling framework, also known as the integrated choice and latent variable (ICLV) model, incorporates psychometric data as indicators of latent variables in the estimation process. Indicators are obtained from responses to behavioral questions. The model consists of two components: a latent variable model and a choice model. Each component incorporates structural as well as measurement equations. The choice model consists of structural equations relating observable and latent variables to the

utility of each alternative, and measurement equations, which link the unobservable utility to choices [27].

Here, the latent variables are explained by a set of characteristics of the individuals and the alternatives (S_{iqr}), through the so-called structural equations, while explaining, at the same time, a set of attitudinal and/or perceptual indicators (y_{ziq}), previously gathered from the individuals, through the so-called measurement equations or CFA. This framework can be represented through the following equations:

$$\eta_{liq} = \sum_r \alpha_{lri} \cdot S_{riq} + v_{liq}, \quad y_{ziq} = \sum_l \gamma_{lzi} \cdot \eta_{liq} + \zeta_{ziq}, \quad (3)$$

TABLE 2: Designated scenarios in the questionnaire.

Scenarios	Time of occurrence	Severity of earthquake
Scenario 1	Day: 8am–12am	Minor
Scenario 2	Night: 12am–8 am	Minor
Scenario 3	Day: 8am–12am	Moderate
Scenario 4	Night: 12am–8am	Moderate
Scenario 5	Day: 8am–12am	Severe
Scenario 6	Night: 12am–8am	Severe
<i>Earthquake Severity Guide</i>		
Minor (3–4.9 Richter)	These earthquakes, in addition to being recorded by seismic devices are also felt by humans, but do not result in significant losses and destructions.	
Moderate (5–6.9 Richter)	This class of earthquakes usually damages the buildings and other urban structures. All the people feel it.	
Severe (7–7.9 Richter)	This class of earthquakes cause mass casualties and damage the urban buildings and structures, especially in developing cities and countries.	

TABLE 3: The structure of latent variables and indicators.

Latent variable	Symbol	Indicator (the number of questions in NEO-FFI)
Neuroticism	N	M21,M26,M31,M36,M41,M46,M51,M56,M1,M6,M11,M16
Extroversion	E	M22,M27,M32,M37,M42,M47,M52,M57,M2,M7,M12,M17
Openness	O	M23,M28,M33,M38,M43,M48,M53,M58,M3,M8,M13,M18
Agreeableness	A	M24,M29,M34,M39,M44,M49,M54,M59,M4,M9,M14,M19
Conscientiousness	C	M25,M30,M35,M40,M45,M50,M55,M60,M5,M10,M15,M20

where the indices i , q , r , l , and z refer to alternatives, individuals, exogenous variables, latent variables, and indicators, respectively. The error terms ν_{liq} and ζ_{zli} can follow any distribution but they are typically assumed to distribute normal with mean zero and a certain covariance matrix. Finally, α_{lri} and γ_{lzi} are parameters to be jointly estimated. Both equations must be continuously processed for their parameter estimation to use as a common variable in the HBLM. The latent variable is added to the fixed utility term so that the utility function includes not only observed variables such as trip characteristics and personal socioeconomic characteristics of passengers but also latent variables such as personality traits. The improved utility function can be expressed as Ref. [28].

$$U_{iq} = \sum_k \theta_{ki} \cdot X_{kqiq} + \sum_l \beta_{li} \cdot \eta_{liq} + \varepsilon_{iq}. \quad (4)$$

The parameters of these exogenous and endogenous variables are then estimated using the maximum likelihood method.

When the assumption of the standard logit model, that is, “parameters are fixed across observations” does not hold, inconsistent estimates of parameters will result [3]. To address the heterogeneity and flexible correlation structure, the random parameters or mixed binary logit model (MBLM) is usually considered. To allow for parameter variations across individuals (represented by variations in β), a mixed model is defined (i.e., a model with a mixing distribution). Mixed logit probabilities are the integrals of standard logit probabilities over a density of parameters that can be expressed in the form of equation (5) [2]:

$$P_i = \int P_{iq}(\beta) f\left(\frac{\beta}{\theta}\right) d(\beta), \quad (5)$$

where $f(\beta/\theta)$ is the density function of β , with θ referring to a vector of parameters of that density function (i.e., mean and variance). The mixed logit model for the probability of individual n for choosing evacuation in the aftermath of an earthquake is

$$P_{ni} = \int \frac{e^{U_{iq}}}{\sum_{A_j \in C_n} e^{U_j}} f\left(\frac{\beta}{\theta}\right) d(\beta). \quad (6)$$

The mixed logit probability is a weighted average of the logit formula evaluated at different values of β , with the weights given by the joint density $f(\beta)$. The values of β have some interpretable meaning as representing the decision criteria of individual decision-makers [4]. This density is a function of parameters θ that represent, for example, the mean and covariance of the β 's in the population. This specification is the same as for standard logit except that β varies over decision-makers rather than being fixed.

4.2. Variables. In order to investigate the choice behavior pattern of individuals after the earthquake disaster, the following variables were considered for modeling as mentioned in Table 5.

Before examining the results of modeling, in order to ensure proper distribution of the explanatory variables, their frequencies were statistically studied. In order to investigate the evacuation choice behavior in response to the earthquake disaster, the frequency percentage of bi-

TABLE 4: The abridged form of questionnaire.

<i>Section 1: Socioeconomic characteristics</i>				
Gender	Male	Female		
Marital status	Married	Single		
Age	18–24 years	25–32 years	33–45 years	
	46–55 years	56–69 years	+70 years	
Education	Diploma and below	Bachelor	Masters	Doctorate
Job	Employee	Manager	Self-employed	Doctor
	Faculty member	Student	Housewife	Retired
	Jobless	Other		
Family Income	Income.			
Number of family members	No. of family members.			
Geographical location of residence	Northern Parts	Central Parts	Southern Parts	
Access to vehicle at emergency situations	No access	Access to vehicle as a driver	Access to vehicle as an occupant	
<i>Section 2: Daily trips' characteristics</i>				
Purpose of daily trips	Education	Work	Entertainment	
	Shopping	Personal affairs	Other	
Traffic condition in daily trips	Very congested	Congested	Normal	
	Uncongested	Very uncongested		
Familiarity with alternative routes	Completely unfamiliar ($\leq 5\%$)	Unfamiliar (5%–20%)	Normal (20%–50%)	
	Familiar (50%–80%)	Completely familiar ($\geq 80\%$)		
<i>Section 3 (Revealed scenario1): Answer to this section according to your decision on the earthquake on December 20, 2017 , 23: 27.</i>				
Did you choose evacuation in response to earthquake on December 20, 2017?	Yes	No		
<i>Section 4 (Designated scenarios): In the questionnaire, the following question is repeated for each of the designated scenarios and people are asked to answer the question according to the severity and time of the earthquake in each of the scenarios.</i>				
Do you choose evacuation in response to this scenario?	Yes	No		
<i>Section 5: NEO-FFI</i>				

nary dependent variable is analysed (Figure 7). The analysis of the results indicates that 46% of people tend to evacuate.

5. Results and Discussion

5.1. Confirmatory Factor Analysis (CFA). NEO-FFI instrument is used to measure the Big Five personality factors. The 60-item NEO-FFI provides a short measure of the Big Five personality factors. For each factor, 12 items are selected [22]. The CFA method is used to estimate all factor loadings and measure the 5 factor of NEO-FFI questionnaire. CFA is a statistical technique used to verify the factor structure of a set of observed variables. CFA allows the researcher to test the hypothesis that a relationship between observed variables and their underlying latent constructs exists [28]. Amos 24 software was used to estimate the CFA. The modeling structure is presented in Figure 8. Latent variables are represented by circles and observed variables by rectangles. Observed variables usually have a measurement error that is represented by circles and single-headed arrows correspond to linear effects. The model parameters were estimated using the maximum likelihood method based on the Amos software. The results show that the estimated models have good fit (Table 6).

5.2. Modeling Analysis. In order to investigate the evacuation choice pattern in response to the earthquake disaster, TBLM was first estimated with the use of observed variables. Then, to investigate the effect of latent variables on the modeling process, HBLM is estimated based on the maximum likelihood approach, which maximizes the probability of a chosen alternative. The modeling results indicate that several factors will affect future evacuation behavior in response to an earthquake disaster. The basic test for the adequacy of the models is the examination of the values and sign of the estimates. The results are achieved from the interpretation of estimated coefficients for the evacuation choice modeling in response to the earthquake disaster (Table 7). By comparing the TBLM and the HBLM, it is obviously seen that the HBLM provides greater explanatory power in evacuation choice behavior, indicating that incorporating the latent variables into the choice model improved the overall goodness of fit of the model. As shown in Table 7, by adding personality traits as latent variables to the modeling process and creating HBLM, the measures of correct prediction percentages, model fit, Pseudo R-squared, and Log likelihood function are increased, indicating that by adding individual personality traits better models are estimated. In both models, the negative sign of estimated coefficients for gender variable indicate that men are less likely to evacuate in response to an earthquake disaster. This

TABLE 5: Independent variables of modeling.

Variable	Variable name: explanation
Gender	GENDER (male = 1, female = 0)
Marital status	Marital status (married = 1, single = 0)
Age	AGE1: 18–24 years, AGE2: 25–32 years, AGE3: 33–45 years, AGE4: 46–55 years, AGE5: 56–69 years, AGE6: +70 years
Education	EDU1: Diploma and below, EDU2: Bachelor, EDU3: Master, EDU4: Doctorate
Job	JOB1: Employee, JOB2: Manager, JOB3: Self-employed, JOB4: Doctor, JOB5: Faculty member, JOB6: Student, JOB7: Housewife, JOB8: Retired, JOB9: Jobless, JOB10: Other
Family Income	Income (Numerical)
Number of family members	No. of family members (Numerical)
Access to vehicle at emergency situations	CARUSE1: No access, CARUSE2: Possible access to vehicle as a driver, CARUSE3: Possible access to vehicle as an occupant
Purpose of daily trips	Trip purpose1: Education, Trip purpose2: Work, Trip purpose3: Entertainment, Trip purpose4: Shopping, Trip purpose5: Personal affairs, Trip purpose6: Other
Geographical location of residence	North: Northern Parts, Central: Central Parts, South: Southern Parts
Traffic condition in daily trips	Traffic1: Very congested, Traffic2: Congested, Traffic3: Normal, Traffic4: Uncongested, Traffic5: Very uncongested
Familiarity with alternative routes	Familiar1: Completely unfamiliar ($\leq 5\%$), Familiar2: Unfamiliar (5%–20%), Familiar3: Normal (20%–50%), Familiar4: Familiar (50%–80%), Familiar5: Completely familiar ($\geq 80\%$)
Earthquake severity	Severity1: Minor, Severity2: Moderate, Severity3: Severe
Time of earthquake	Time (night = 1, day = 0)

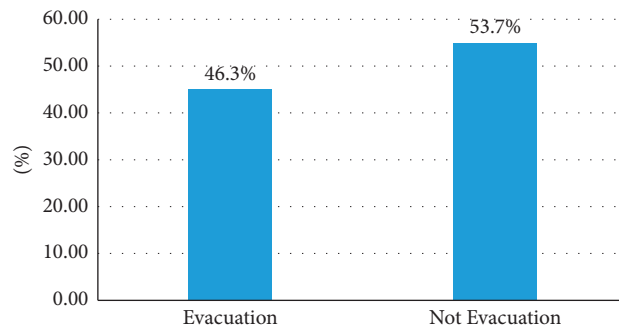


FIGURE 7: Frequency distribution of action choice in response to earthquake.

finding is consistent with the finding of previous research by Bateman and Edwards, which concluded that women are more likely to evacuate compared to men because of socially constructed gender differences in care-giving roles, access to evacuation incentives, exposure to risk, and perceived risk. Individuals in the age groups of 18–24 and 25–32 are more likely to evacuate in TBLM while the age group 33–45 is also significant in HBLM, and it indicates that people in the age group of 33–45 have a positive contribution to evacuation. The positive sign and bigger amount of estimated coefficient for AGE1 ($\beta = 3.611$) indicates that individuals in the age group of 18–24 tend more to evacuate. This finding is consistent with the results of studies by Yang et al. [16] which indicated that young persons are more likely to evacuate. Although marital status is not a significant factor in TBLM, the estimated coefficient of HBLM indicates that married individuals are more likely to evacuate (coefficient = 2.657). Protecting each other before protecting oneself is also a common explanation for the fact that married individuals were found to be more likely to evacuate in response to an earthquake. In both models, with the increase in the number

of family members, the tendency to evacuate also increases. In contrast, family size is not significantly correlated with evacuation in the study of solis et al. HBLM indicates that people who do not have accessibility to a car in emergency situations have less tendency to evacuate in response to an earthquake disaster (coefficient = -2.586). The coefficients indicate that people who have access to a car as a driver or occupant are more likely to evacuate in a convenient way in response to an earthquake disaster. The negative sign of estimated coefficient for NORTH variable indicates that people who stay in the northern parts of the city are less likely to evacuate. It can be because of new construction in this area and more confidence of people in the strength of the buildings. The positive sign of the estimated coefficient for TRAFFIC3 variable indicates that individuals facing normal traffic on their daily trips have more tendency to evacuate in the hybrid model. The negative sign of the estimated coefficient for FAMILIAR2 variable in both models indicates that people who are unfamiliar with alternative routes are less likely to evacuate. It can be because of the sense of being blocked in routine routes. While SEVERITY3

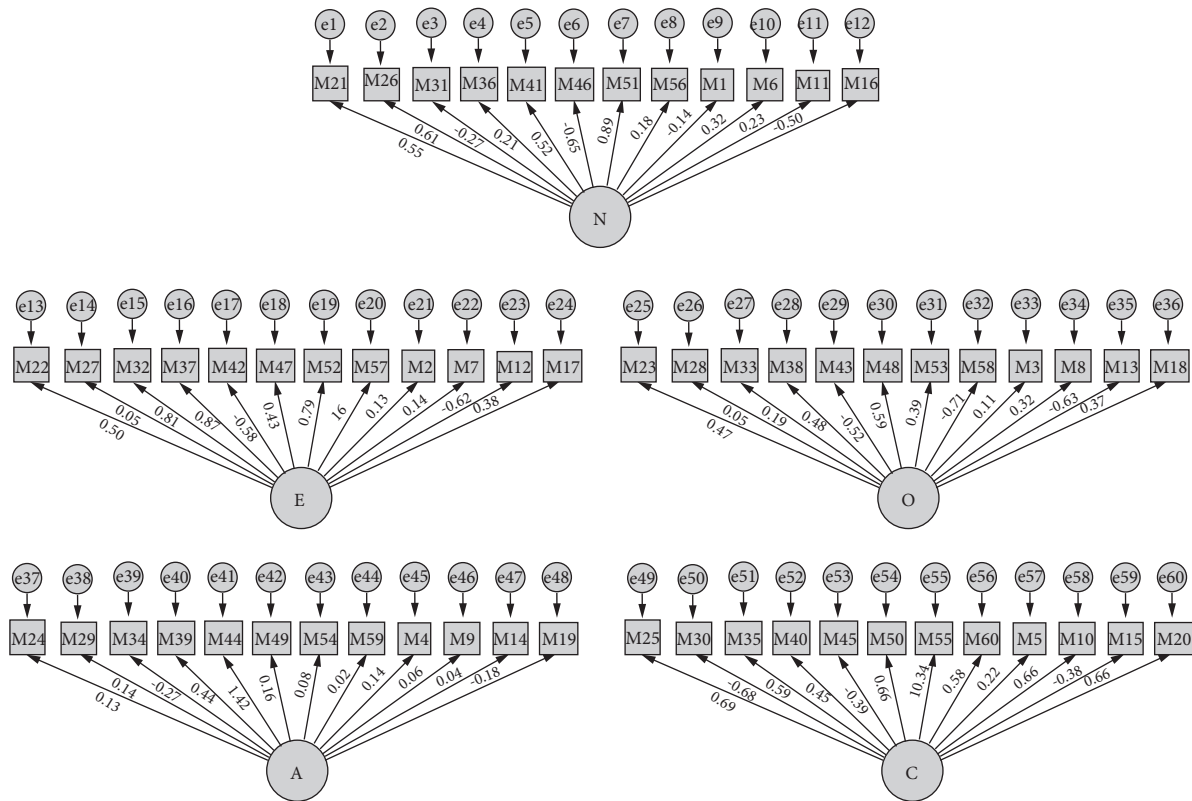


FIGURE 8: The confirmatory factor analysis structure.

TABLE 6: Modeling fit indices.

Fit index	Value	Criteria of good fit
Chi-square/degree of freedom (CMIN/DF)	4.791	<5
Root mean square error of approximation (RMSEA)	0.079	≤0.08
Goodness-of-fit index (GFI)	0.939	0.9≤
The parsimonious normal fit index (PNFI)	0.514	0.5<
Comparative fit index (CFI)	0.918	0.9≤
Root mean square residual (RMR)	0.018	Good models have small RMR

variable is not significant in TBLM, the signs of the estimated coefficients for SEVERITY1, SEVERITY2, and SEVERITY3 variables in HBLM indicate that as the severity of the earthquake increases, the tendency to evacuate increases. The positive sign of the estimated coefficients for time in both models indicate that people are more likely to evacuate at night. The positive sign of estimated coefficients of HBLM indicate that people with more neuroticism, extraversion, openness, and conscientiousness factor are more likely to evacuate while people with more agreeableness factor are less likely to evacuate (coefficient = -0.522). As neuroticism refers to the propensity to experience negative emotions, anxiety, and psychological distress in response to threats; extraversion represents the tendency to enjoy social situations and interpersonal relationships; openness to experience reflects the tolerance of ambiguity; and conscientiousness implies both proactive and inhibitive aspects, such as competence, striving to achieve, and cautiousness, it is expected that people with these factors in their

personality are more likely to evacuate. However, agreeableness denotes the quality of interaction “along a continuum from compassion to antagonism,” having facets of trust and altruism [22]. Therefore, it is reasonable that people with more agreeableness factor are less likely to evacuate.

Since the occurrence of an earthquake is one of the situations in which a person can decide based on his/her perception whether to evacuate or not, the MBLM was also calibrated to analyse the behavior of individuals comparing to TBLM and HBLM. This model is one of the most flexible structures of discrete choice models, which can be used to estimate almost any other structure in random utility models. A very good description of this model and its features was provided in 2000 by McFadden and Train [29]. This model allows for changes in random tastes, the use of a variety of substitution patterns, and correlations in the unobserved component over time for the model maker. The MBLM can be estimated and interpreted based on a wide

TABLE 7: The results of TBLM and HBLM.

Independent variable	TBLM		HBLM	
	Estimated coefficient	<i>P</i> value	Estimated coefficient	<i>P</i> value
Gender	-0.279**	0.0239	-0.417**	0.0144
Age1	1.324***	≤0.001	3.611***	≤0.001
Age2	1.244***	≤0.001	1.721***	0.0002
Age3	—	—	1.926***	0.0003
Edu2	-1.237***	≤0.001	-1.780***	≤0.001
Edu3	-2.418***	≤0.001	-0.922*	0.0689
Marital status	—	—	2.657***	≤0.001
Job7	1.240***	≤0.001	1.006***	0.0009
Car Use1	—	—	-2.586***	≤0.001
Car Use2	0.725**	0.0377	-1.094**	0.0338
Car Use3	0.761**	0.0127	-1.423***	0.0002
Trip Purpose2	0.962***	≤0.001	-0.895***	0.0001
North	—	—	-0.260*	0.0969
Traffic3	-0.360***	0.0084	—	—
Familiar2	-1.182***	≤0.001	-1.243***	0.0014
Severity1	-1.691***	0.0002	-1.281**	0.0120
Severity2	-1.691***	≤0.001	-1.199**	0.0218
Severity3	—	—	2.848***	0.0002
Time	0.261***	0.0057	0.249**	0.0109
Income	0.097**	0.0176	—	—
No. of family members	0.177*	0.0799	0.771***	≤0.001
N	—	—	0.229***	≤0.001
E	—	—	—	—
O	—	—	0.636***	≤0.001
A	—	—	-0.522***	≤0.001
C	—	—	0.104***	0.0028
Log likelihood function	-1406.783		-1308.464	
Chi-squared	215.986		412.62358	
McFadden pseudo R-squared	0.071		0.136	
Correct prediction (%)	54.881		58.485	
False prediction (%)	45.027		41.423	

range of behavioral characteristics, depending on the modeller. In the random coefficient model, random parameters are assumed to be randomly distributed over the population to capture the taste variation of the individual. As can be seen in Table 8, based on the model fit indices such as increasing in Log Likelihood function and pseudo square (ρ^2), MBLM is fitted better than the other models. The result of MBLM depicts that Age1, Marital status, Severity1, Severity2, and Severity3 are significant as nonrandom parameters in utility functions. The Age1, Marital status, and Severity3 variables have positive signs in $U(1)$ utility function. The results indicate that young (18–24 years old) and married individuals are more likely to get evacuated. Severity1 and Severity2 variables have positive signs in $U(0)$ utility function. These signs indicate that people are more likely not to evacuate in minor and moderate severity of earthquakes. These results are in accordance with the results of HBLM.

In addition, results show that income, number of family members, and five factors of personality traits are heterogeneous variables and these variables are significant as random parameters in MBLM. In other words, their effect is different. For instance, although the effect of income variable is positive for choosing evacuation, with the increase in income, the willingness of individuals to evacuate increases;

this effect is different for each of the respondents. This finding might be explained by the differences in the mindset of individuals. Increase in income can lead to having more required equipment for evacuation and more willingness to evacuate. On the other hand, increase in income can lead to having houses with more resistance and more confidence of people in the strength of their buildings and less willingness to evacuate. Besides, the number of family members is heterogeneous in the utility function of not choosing evacuation. Thus, it can be stated that the negative effect of the number of family members on not choosing evacuation is not the same for all the respondents. This finding might be explained by the differences of individuals in decision-making. As mentioned, five factors of personality traits are significant as random parameters in MBLM. Although the effect of openness and conscientiousness variables are positive in $U(1)$ utility function and as the openness and conscientiousness factors increase, the willingness of individuals to evacuate increases; this effect is different for each of the respondents according to the amount of self-control in their personality. Furthermore, although the effect of agreeableness factor is positive in $U(0)$ utility function and as the agreeableness factor increases, the willingness of individuals not to evacuate increases; this effect is different for each of the respondents according to the amount of

TABLE 8: The result of random parameters/mixed logit model.

Independent variable	Estimated coefficient	P value
<i>Nonrandom parameters in utility functions</i>		
Constant	-77.532***	0.0002
Age1	24.405***	0.0048
Marital Status	32.873***	0.0013
Familiar2	—	—
Severity1	36.321***	0.0055
Severity2	32.833***	0.0073
Severity3	28.209**	0.0313
<i>Random parameters in utility functions</i>		
Income	2.663**	0.0255
No. of family members	-13.216***	0.020
N	-0.533*	0.0488
E	-1.800**	0.0247
O	4.967***	0.0034
A	1.656*	0.0683
C	1.979**	0.0122
<i>The standard deviation of random parameters</i>		
Income	0.749*	0.0421
No. of family members	1.789*	0.0213
N	0.757*	0.0701
E	1.467***	0.0062
O	3.310*	0.0645
A	0.696*	0.0320
C	0.790**	0.0182
Log likelihood function		-328.410
Chi-squared		97.32
McFadden Pseudo R-squared		0.149

Utility functions of mixed logit model: $U(1) = \text{Evacuation choice}$, $U(0) = \text{Not evacuation choice}$,
 $U(1) = a_1 + a_2 * \text{Marital status} + a_3 * \text{Familiar2} + a_4 * \text{Age1} + a_5 * \text{O} + a_6 * \text{C} + a_7 * \text{Severity3} + a_8 * \text{Income}$,
 $U(0) = a_9 * \text{A} + a_{10} * \text{Severity1} + a_{11} * \text{No of family members} + a_{12} * \text{Severity2} + a_{13} * \text{N} + a_{14} * \text{E}$.

cooperativity in their personality. Besides, neuroticism and extroversion factors are heterogeneous in the utility function of not choosing evacuation. Thus, it can be stated that the negative effect of neuroticism and extroversion factors on not choosing evacuation is not the same for all the respondents. This finding might be explained by emotional instability and self-consciousness of individuals. The standard deviations of random parameters are significantly different from zero, which implies that different individuals in the same income, number of family members, and same personality traits perceive the alternatives' utilities differently.

6. Conclusion

Many researchers have examined the factors affecting evacuation decision in response to natural hazards but most of the previous studies have investigated the effect of socioeconomic factors on trip choice behavior and study about the role of personality traits on evacuation choice behavior is neglected. Hence, this paper focuses on examining the effect of personality traits on evacuation choice behavior in response to an earthquake disaster. The study was conducted in the city of Qazvin and the RP and SP methods were used for data collection. RP data were based on the real

earthquake experience of December 20, 2017 and SP data were collected from field survey assuming six hypothetical earthquake scenarios with three different severities in two times (day-night) of the day. Personality traits as latent variables were obtained from the CFA of NEO-FFI.

First, TBLM was used for identifying effective socio-economic characteristics and earthquake characteristics on the evacuation choice of individuals. Then, by applying the HBLM, the role of the personality traits as latent variables on evacuation choice behavior is obtained. The results from the HBLM are more comprehensive than those from the TBLM since it accounts for factors that impact decisions on evacuation choice. The results of HBLM show that personality traits make a significant contribution to people's evacuation decision in response to an earthquake disaster. Results also indicate that gender, marital status, and family size have a positive impact on evacuation choice, while no possible access to vehicle, residence in north parts of the city, and unfamiliarity with alternative routes have a negative impact on evacuation choice. As the severity of the earthquake increases, the tendency of people to evacuate also increases. In earthquakes occurring at night, the tendency of people to evacuate is more. People with high neuroticism, openness, and conscientiousness personality factors are more likely to evacuate, while people who have a high

agreeableness personality factor are less likely to evacuate.

Also, the effect of taste variation of personality traits on evacuation choice behavior was investigated using MBLM. The model concludes that different individuals with the same family income, the same number of family members, and the same neuroticism, extroversion, openness, agreeableness, and conscientiousness factors of personality traits can perceive the alternatives' utilities differently.

This study is expected to provide a better understanding for urban planners on the influential factors of evacuation choice behavior in emergency situations like an earthquake. Results of this study can be used for pre-disaster planning. The results of this study can be related to identifying the general behavior of users and estimating their reactions in times of crisis, providing the needed training for users in times of crisis, strengthening network components according to possible destinations, forecasting transportation network demand in the event of a crisis based on the reaction of users, forecasting the conditions of the transportation network after the crisis in order to make the necessary plans, including routing and managing ambulances, designing city escape routes, and locating shelters needed to accommodate people in the situation of an earthquake crisis.

There are some recommendations for future researches. In order to provide future directions and way forward to the study, the following suggestions are presented:

- (i) Future research could include gathering more information about other decision-making variables about choice behavior in response to an earthquake crisis such as cultural beliefs, following others, etc.
- (ii) Explaining hypothetical scenarios for the two seasons of summer and winter can be another suggestion for future research.
- (iii) Studying the mode, destination, and route choice behavior to predict the status of transport network links after the earthquake crisis helps to complete the research.

Data Availability

Some parts of data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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