Decision Making on Evacuation from the Tsunami Following the Earthquake off Kuril Islands in 2006

by

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ABSTRACT

This paper builds and examines a model of decision making on evacuation from the tsunami in November 2006. A questionnaire survey on actions etc. after the evacuation order was conducted in Kushiro City, and the model was examined through a structural equation modeling. The results show that intention to evacuate was related to concern over inundation, resources on evacuation, and experiences of tsunami damage and evacuation, and that social capital had close relation to interest in disaster prevention.

KEYWORDS: Evacuation, Social Capital, Structural Equation Method, Tsunami

1. INTRODUCTION

Storm surge disaster has frequently occurred both in and out of Japan in the past several years, and large-scale tsunami disasters are expected to occur in the future. However, in reality, there are many residents who do not evacuate despite their recognition of the need to do so due to normalcy bias and other factors, even when a typhoon approaches or a tsunami warning is issued.

On the other hand, social capital is drawing attention in the context of disaster prevention, together with volunteers, community development activities, and international cooperation. Social capital is a characteristic of social organization, with others being "trust," "norms of reciprocity," and "network of civic engagement," and is known to enhance the efficiency of society by activating people's cooperative action.

In general the occurrence of tsunami is characterized by long intervals. Given this characteristic, it is important to hand down the lessons learned from past disasters and communicate a picture of expected damage to residents in disaster prevention. It is necessary to have neighbors call out to each other to evacuate and to support mobility-impaired residents during evacuations, and to engage in local efforts toward restoration and rehabilitation after damage has been suffered. These actions cannot be easily realized without residents' having close ties with their neighbors and enthusiasm for participation in disaster drills. Accumulation of social capital is thus required.

For evacuation from a tsunami, it has been noted that people excessively depend on evacuation information or tsunami warnings when they make decisions about evacuation, that people tend to have too optimistic a view about danger, and that people's impressions of tsunami tend to be fixed based on their past experience [1]. A report from the Tokachi-oki Earthquake in 2003 indicates that those who, immediately after they felt a big tremor, clearly understood that they were in danger unless they evacuated were actually able to evacuate swiftly [2]. The Cabinet Office conducted a nation-wide survey on social capital [3] and reported some noteworthy findings about its relationship with disaster prevention. However, there are no reports where the action of evacuation from a tsunami was analyzed out of the need to consider social capital.

In this research, which views social capital as the basis for local people's historically formed disaster prevention capability, we surveyed evacuation decision-making factors for the purpose of reviewing measures to promote

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evacuation.

2. SURVEY METHOD

2.1 Outline of Survey

On November 15, 2006, a tsunami warning was issued in the area of Hokkaido facing the Okhotsk Sea and the eastern coast facing the Pacific following an earthquake that occurred off the Kuril Islands. All local governments located in the concerned coastal areas issued an evacuation directive and order (to 130,804 residents). Kushiro City, where the seismic intensity was recorded to be only 1, issued an evacuation order, simultaneously with the tsunami warning (8:29 pm), to 2,561 households (4,675 residents) in the areas in which evacuation is necessary when a tsunami of 3 meters or less is expected based on the Tsunami Hazard Map of Kushiro City [4] and the Onbetsu area (i.e., the area seaward from the track of the Nemuro Main Line). The first tsunami waves hit the coast at a height of 0.2 meters at 9:43 pm; however, the waves never exceeded 0.3 meters in height, and no damage was done. At 11:30 pm. when the tsunami warning was switched to a tsunami advisory, the evacuation order was cancelled.

To clarify what factors differentiated those who evacuated from those who did not, a questionnaire survey was conducted that targeted residents in the area of Kushiro City, Hokkaido, that was subjected to the evacuation order.

2.2 Past Tsunamis in Kushiro and Present Measures

Kushiro City faces the Pacific Ocean. The Kushiro River, New Kushiro River and Akan River flow through the city area and drain into the sea. Learning from a flood of the Kushiro River that occurred in 1920 and inundated the city area, the government started excavation of a new water channel (to become the New Kushiro River in 1931). When the Tokachi-oki Earthquake occurred on March 4, 1952, Hamanaka Town, east of Kushiro City, were inflicted with serious damage by a resulting tsunami. While the height of this tsunami was about 0.9 meters at Kushiro City, damage by the earthquake itself was greater. Tsunami damage was minor following the Chile Earthquake that occurred on May 24, 1960. The Kushiro-oki Earthquake on January 15, 1993, shook the city at a seismic intensity of about 6, and damage caused by the seismic motion was serious. When the Tokachi-oki Earthquake struck on September 26, 2003, the city was severely jolted, and 193 residents evacuated voluntarily.

As stated above, Kushiro's citizens have almost never experienced tsunami damage. Nonetheless, the Central Disaster Prevention Council predicts that major earthquakes with epicenters somewhere in the Kuril Trench occur at intervals of 500 years. In response, Kushiro City distributed a new hazard map based on tsunami-inundated areas predicted by Hokkaido Government in 2007. In addition, voluntary disaster prevention and mitigation activities are aggressively conducted, including surveys on citizens' awareness of tsunami evacuation and disaster "desk drills" by the Kushiro City Federation of Disaster Prevention Promotion Councils (a federation of voluntary disaster prevention organizations). However, these activities are experiencing some problems, including falling participation in disaster prevention efforts as well as fewer people taking the lead in disaster prevention due to hollowing out of the city center.

2.3 Survey Method

A questionnaire survey was conducted and recovered answers from respondents to questions on the following: the number of co-inhabitants; presence or absence of mobility-impaired people and car drivers; type of housing and number of stories; fear of seismic motion; anticipation of inundation and related danger; recognition of warnings and evacuation orders; intention to, preparation for, and action concerning evacuation; presence or absence of mutual alerting to evacuate; experience of disaster or evacuation; status of participation in disaster prevention drills; recognition of the circulated hazard map (Kushiro Anshin Map), shelters, and expected inundation areas; recognition of past disasters

and memories of past disasters; desire to live in the neighborhood permanently; and social capital (trust of others, neighborhood socialization, activities based on community bonds, individual activity, etc.). Questions about social capital included the same questions asked by the Cabinet Office survey [3] for comparison. The questionnaire also clearly stated that the subject earthquake, which occurred in November 2006, is different from another earthquake that occurred off the Kuril Islands on January 13, 2007, after which a tsunami warning and evacuation order were also issued, so that no confusion between them should occur.

In order to prevent biasing of samples by location or type of housing, the number of households to be candidate subjects of the questionnaire survey was allocated by a unit set by combining such attributes as the zone of elevation (below 2 meters and 2 meters or higher), expected inundation depth (below 1 meter and 1 meter or higher), and type of housing (detached or collective) for each block in the areas to which an evacuation order is to be issued, and the households to be surveyed were selected from those at random.

The questionnaire was handed in person to 557 households and delivered to 93 households from December 15 to 17, 2007. Questionnaire answers were returned by mail, postage collect. The recovery ratio was 46% (302 households); however, one questionnaire was left blank.

3. SURVEY RESULTS

3.1 Attributes of Respondents

The sizes of the respondents' households were relatively small, as shown by the ratio of household size, or 31.2% for single-person households, 34.9% for two-person, and 18.6% for three-person. The survey revealed that 18.2% are households with residents who cannot easily evacuate on foot. As for types of housing, detached houses occupy 58.7%, while collective housing accounts for 42.2%. For the number of stories, flat houses occupy 5.0%, two-storied 65.4%, three-storied 4.3%, and four-storied or higher 24.9%. For the floor where respondents stay the longest, the first floor accounts for 56.5%, 2nd floor 20.9%, 3rd floor 4.7%, 4th floor 5.3%, 5th floor 9.3%, and 6th floor or higher 2.3%.

3.2 Information on Respondents' Locations

Information on the respondents' locations, loudspeaker car routes, and the locations of PA radio facilities were input into a geographical information system, and then the elevations of the residents' homes, expected inundation depth (in the case of a once-in-500-years earthquake), distance from the coastline, distance from the waterfront (i.e., the closest coastline or river), distance from the evacuation area, distance from loudspeaker car routes, and distance from disaster PA radio facilities (outdoor speakers) were measured. An outline of the results is provided below:

- For the elevation of the respondents' homes, homes below 1 meter in elevation account for 1.7%, 1 to 2 meters 60.5%, and 2 to 3 meters 29.2%.
- For the expected inundation depth, homes expected to be inundated to a depth of less than 0.5 meters account for 37.2%, 0.5 to 1.0 meters 42.9%, and 1.0 to 1.5 meters 11.0%. Of all respondents' houses, 5.6% have an expected inundation depth of zero meters.
- For distance from the coastline, 48.2% are over 1,000 meters away, meaning a relatively high number of homes are located away from the coastline. This is because it is expected to be flooded by tsunamis through the Kushiro River.
- For the distance from the waterfront, 19.9% are less than 100 meters away, 33.6% are 100 to 200 meters, and 28.2% are 200 to 300 meters. No households are beyond 1,000 meters.
- For the distance from the designated evacuation area, 88.0% are less than 400 meters away.
- For the distance from a loudspeaker car route, 91.0% are less than 100 meters away.
· For the distance from a disaster information PA radio facility, 27.6% are less than 100 meters away, 37.5% for 100 to 200 meters, and 17.3% for 200 to 300 meters.

3.3 Simple Summation of the Responses

3.3.1 Fear of Tremor

As shown in Figure 1, the tremor of the subject earthquake was no more fearful than that of an ordinary earthquake for over two-thirds of the respondents.

3.3.2 Expectation of Inundation and Danger to Life

As shown in Fig. 2, the respondents who thought their homes "would surely be inundated" or "would probably be inundated" in the subject earthquake together occupy only about 5%. Asked the depth to which they thought their homes would be inundated, 1.0% of the respondents answered "up to the 2nd floor," 2.3% "to the level of the floor," 5.3% "below the floor level," 24.9% "around the house," and 61.1% answered they "never thought the house could be inundated." For danger to life, as shown in Fig. 3, 5% of the respondents "thought I would not be safe unless I evacuate" or "thought I could die unless I evacuate." Thus, only a small number of respondents anticipated inundation or danger to life due to the earthquake.

3.3.3 Recognition of Warning and Evacuation Order

Of the respondents, 72.4% knew a tsunami warning was issued, and 23.9% did not. Those who knew were asked how they learned of the warning, with multiple answers allowed; of them, 85.3% said TV, 46.8% said loudspeaker car or fire engine, 14.2% said outdoor speaker, 14.2% said radio, and 4.6% said neighbors. The fact that many chose loudspeaker car, fire engine or outdoor speaker is probably due to the fact that many respondents lived near a loudspeaker car route or PA radio facility.

Of the respondents, 65.8% knew that an evacuation order was issued, while 26.6% did not. When those who knew were asked how they learned of the order, with multiple answers allowed, 82.8% indicated TV, followed by 56.1% for loudspeaker car or fire engine, 18.7% for outdoor speaker, 9.6% for radio, and 5.6% for neighbors. This trend is similar to that of warning, but compared with the case of warning, the ratio for TV is smaller, while those for outdoor speaker and neighbors were slightly greater.

3.3.4 Intention and Preparation for Evacuation

The respondents were asked if they intended to evacuate following the subject earthquake regardless of whether or not they knew of the evacuation order. As shown in Fig. 4, those who "thought I must evacuate" and "thought I should evacuate" together accounted for about 30%.

Answering another question about whether they prepared for evacuation or not, 16.6% of respondents "checked the location of the evacuation area and prepared items to take," 26.9% "checked the location of the evacuation area but did not prepare items to take," and 50.8% "did not prepare for evacuation."

3.3.5 Evacuation, Starting Time, and Means of Transportation

Of all of the respondents, 28.6% evacuated and 67.8% did not; 3.7% gave no answer. The ratio of those who evacuated roughly agrees with the previously mentioned ratio of people who leaned toward evacuation.

Eighty-six respondents who evacuated were asked at what time they did so. As shown in Fig. 5, over three-fourths of the evacuees left their homes for an evacuation area by the time immediately after the issuance of the evacuation order.

For the means of transportation, 67.4% used cars, 24.4% walked, and 4.7% used bicycles. Thus, many respondents used cars for evacuation.

3.3.6 Motivating Factor for Evacuation and Reason not to Evacuate

The 86 evacuees were asked what motivated them to evacuate. As shown in Fig. 6, many of them gave the issuance of the tsunami warning or evacuation order. In addition to calls for evacuation from TV and radio stations, the city hall or fire department, a relatively large percentage of respondents said they decided to evacuate because neighbors called on them to evacuate together.

The 204 respondents who did not evacuate were

asked why they did not. As shown in Fig. 7, the most common answers were, in descending order, "did not think a big tsunami would occur," "monitored the situation on TV," and "no neighbors evacuated." Some answered "I have family members who are physically disabled" or "I could not evacuate by myself." This suggests the need to support residents who require care in evacuation.

3.3.7 Mutual Calls for Evacuation

Of the respondents, 9.6% were called on to evacuate by neighbors, while 62.8% were not. Conversely, 10.0% called on their neighbors to evacuate, while 79.1% did not.

3.3.8 Experience of Disaster and Experience of Evacuation

Respondents were asked about their experience with tsunami disasters, and 74.1% said they "had not experienced any tsunami damage," 5.3% "experienced tsunami damage caused by the Tokachi-oki Earthquake in 1952," and 5.0% "experienced tsunami damage caused by the Chile Earthquake in 1960." Asked about experience with damage other than tsunami, 40.9% "had not experienced any damage other than tsunami," and 27.6% "experienced damage caused by the shaking of an earthquake." Although few residents had suffered tsunami damage, a relatively large number of people had experienced earthquake damage other than tsunami.

To a question about their experience in evacuating from a tsunami, the majority of respondents, or 46.5%, answered they "had never evacuated from a tsunami." But 11.0 to 17.9% had evacuated following earthquakes, including the Hokkaido Toho-oki Earthquake in 1994, Tokachi-oki Earthquake in 2003, Kushiro-oki Earthquake in 1993, and Tokachi-oki Earthquake in 1952.

3.3.9 Interest in Disaster Prevention

Of the respondents, 70.8% had never participated in disaster drills, while 8.6% participate in them every year.

The percentage of respondents that had seen Kushiro Anshin Map was 75.4%, which is far greater than the ratio of those who had not (20.6%).

Asked about the evacuation area, 76.7% answered it is "within walking distance," 5.3% said it is "beyond walking distance," and 12.6% "don't know where it is."

Asked if their home is in the expected inundation area or not, many respondents, or 77.1%, indicated that they know their home is in the expected inundation area, while those who did not know account for 13.6%.

When subject residents were asked about serious damage caused by a devastating flood in Kushiro in 1920, many of them, or 59.8%, had "never heard of it." Those who "know about it in detail" and "heard of it" only accounted for 3.3% and 34.6%, respectively.

3.3.10 Social Capital

When asked about their trust of others, 9.6% answered they "can trust most people," 40.9% think "there are more trustworthy people than not," 38.2% "cannot say either way," 6.3% said "there are more untrustworthy people than trustworthy people," and 1.7% "can't trust most people." Compared with the nation-wide survey done by the Cabinet Office, the sense of trust in others is higher in this survey.

When asked about degree of socialization with their neighbors, 13.6% said they "cooperate with neighbors in daily living; for example, in mutual consultation or lending/borrowing of daily commodities," 36.2% "socialize with neighbors on daily chatting terms," 42.2% "engage in a minimum level of socialization; e.g., are just on greeting terms," and 5.6% "do not socialize with neighbors." As for their desire to live in the neighborhood permanently, 33.6% "want to live permanently," 15.3% "would rather live permanently," "25.2% "can't say either way," 8.0% "would rather not live permanently," and 15.9% "don't want to live permanently." The results for degree of socialization with neighbors and desire to live in the neighborhood permanently are slightly lower than those of the

Cabinet Office's nation-wide survey.

Asked about participating in activities that are based on community bonds, many respondents, or 52.5%, "don't participate in such activities," 24.6% "participate a few times a year," and 7.0% "participate about once a month." The ratio of respondents who participate in volunteer activities, NPO, or civil activities is about 20%.

4. ANALYSIS OF DETERMINING FACTORS IN EVACUATION DECISION-MAKING

4.1 Analytical Method

The questionnaire survey asked questions about what made residents decide to evacuate or why they didn't evacuate. It is recognized that their answers may contain some bias that justifies their action. To clarify the relationship between various factors, including recognition of the evacuation order, and evacuation action, a covariance structure analysis was conducted using AMOS with such observed variables as the respondents' answers and locational information of the respondents compiled by the geographical information system.

As shown in Fig. 8, the hypothesis used in this verification was established based on the previous research results, with evacuation action separated from intention to evacuate, and the factors concerning intention to evacuate set as latent variables (surrounded by ovals). To increase the appropriateness of the model, the final path diagram of Fig. 9 was obtained by narrowing down the observed variables of the latent variables (surrounded by squares in Fig. 9) based on the results of factor analysis and eliminating the paths that lead to inappropriate solutions.

4.2 Analysis Results

As indicated in Fig. 9, the path coefficients (arrow subscripts) indicate the correlation between factors. Since this figure is a standardized solution, the closer the absolute value of the path coefficient is to 1, the greater the correlation between factors. Since GFI and AGFI of the model are below 0.9, the model's appropriateness is not sufficiently high; however, the model is still considered appropriate enough to estimate the relationship between factors.

Focusing on the path coefficients, we can clearly see a path leading from concern over inundation to intention to evacuate and from intention to evacuate to evacuation action; however, recognition of evacuation information has little to do with concern over inundation or intention to evacuate. While the part of the result where concern over inundation is connected to intention to evacuate agrees with the corresponding result of the survey made by Yoshii et al. [2], it is understood that concern was affected by previous experience and fear of tremors. Unlike the answers on motivating factor for evacuation, a certain tendency is suggested whereby recognition of a tsunami warning or evacuation order has little effect on evacuation action. Although recognition of the hazard map and evacuation areas and experience of participation in disaster drills are important, it is possible that interest in disaster prevention alone will not directly lead to evacuation.

Intention to evacuate has a relatively strongly relationship with previous experience and resources on evacuation as well as concern of inundation. This finding puts importance on sharing of disaster and evacuation experience, measures to support people who require assistance, and development of neighborhood evacuation areas when promoting evacuation.

Social capital is greatly related to interest in disaster prevention. Separately conducted factor analysis on all of the observed variables found that the observed variables related to social capital, excluding trust of others, (i.e., participation in activities based on community bonds, socialization with neighbors, and desire to live in the neighborhood permanently) are greatly affected by the same factors as the observed variables related to interest in disaster prevention, such as participation in disaster drills. This finding indicates that the part of social capital that is related to the local community may probably encourage recognition of evacuation information or evacuation action by enhancing residents' interest in disaster

prevention. Note that large path coefficients are also derived from calculation by reversing the arrows from social capital to interest in disaster prevention, suggesting close ties between them bilaterally.

5. CONCLUSIONS

As discussed above, our survey suggests the possibility that the evacuation information provided when the evacuation order was issued had little connection with concern over inundation or evacuation action. This indicates a disassociation between recognition of a tsunami warning or evacuation order and recognition of inundation risk. Elimination of such disassociation or reinforcement of factors related to intention to evacuate based on the assumption of such disassociation should work to encourage evacuation action. One step toward eliminating the disassociation would be thorough communication of the importance of tsunami warnings and evacuation orders. Promising actions to reinforce the factors related to intention to evacuate include simulated disaster experience through visualization of past or expected damage or participation in evacuation drills and improvement of the evacuation environment, including support for people who need assistance and reduction in evacuation distance. It is also important to accumulate social capital to enhance people's interest in disaster prevention.

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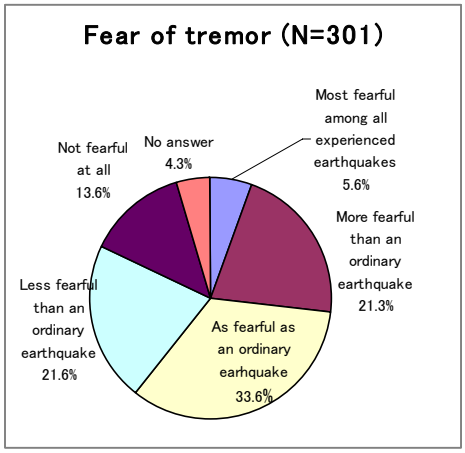

Fig.1 Fear of Tremor

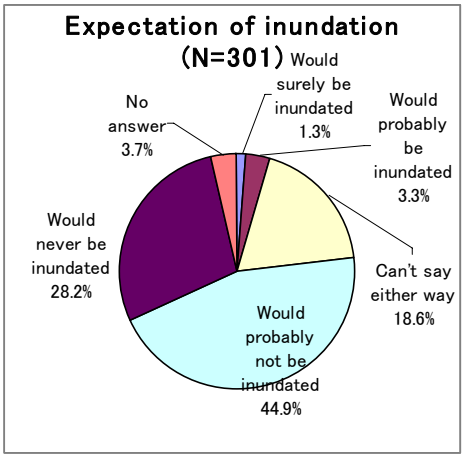

Fig.2 Expectation of Inundation

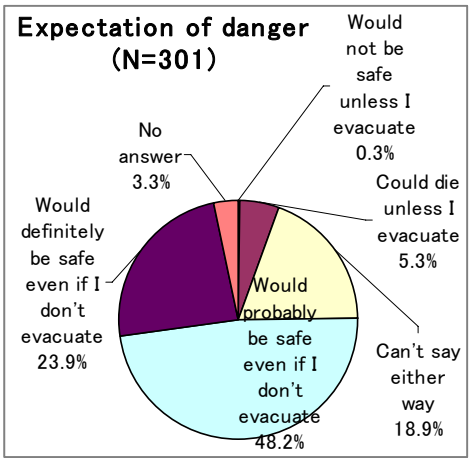

Fig.3 Expectation of Danger

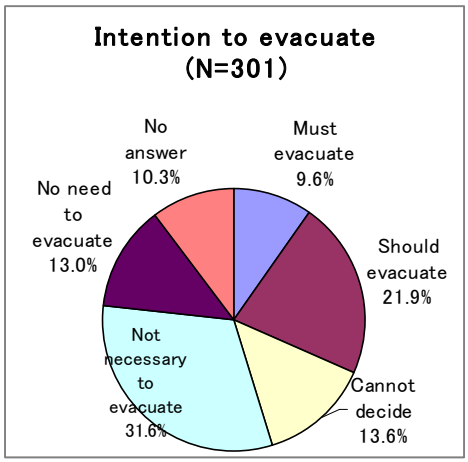

Fig.4 Intention of Evacuate

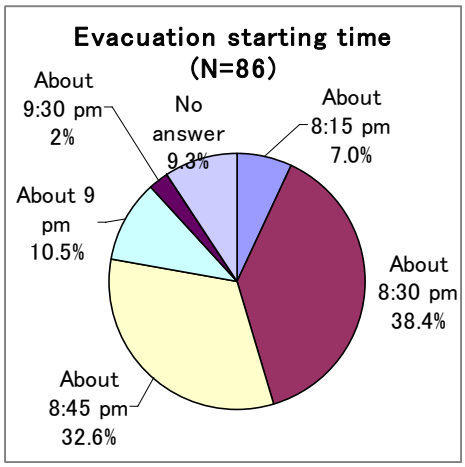

Fig.5 Evacuation Starting Time

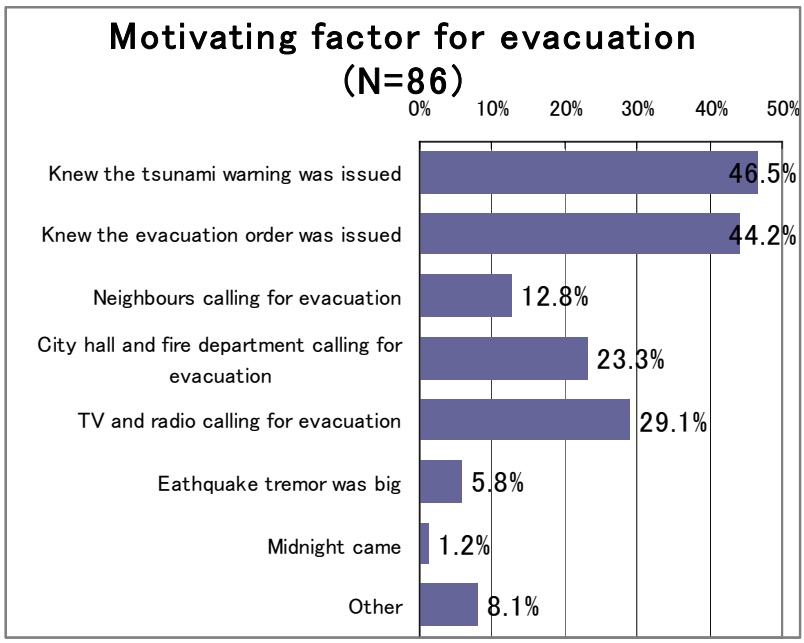

Fig.6 Motivating Factor for Evacuation (multiple answers allowed)

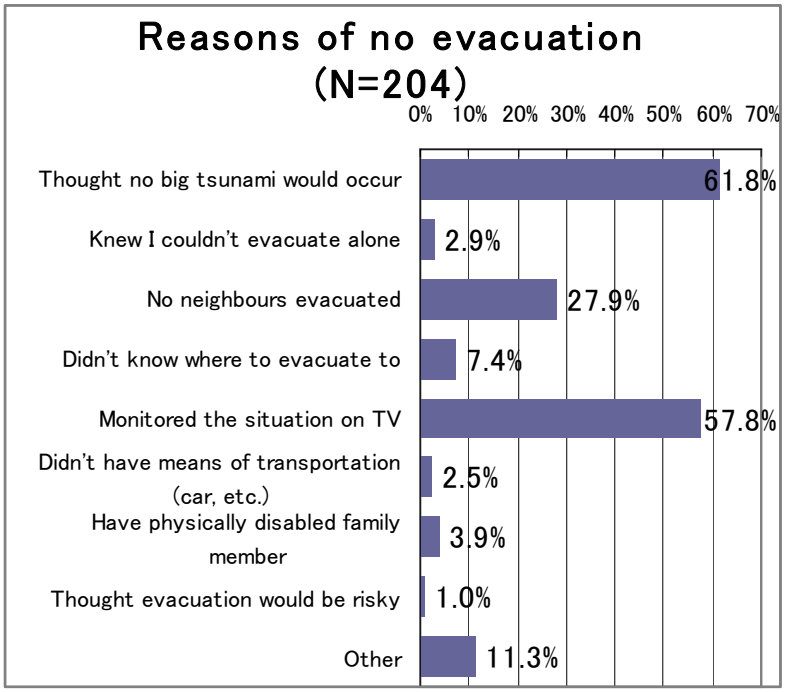

Fig.7 Reasons of No Evacuation (multiple answers allowed)

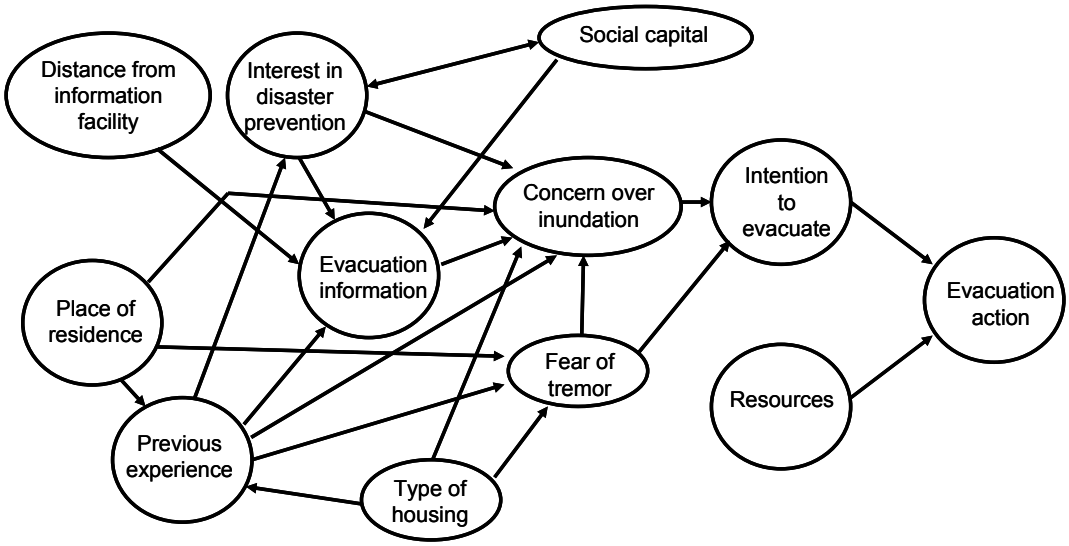

Fig.8 Hypothesis of Evacuation Action

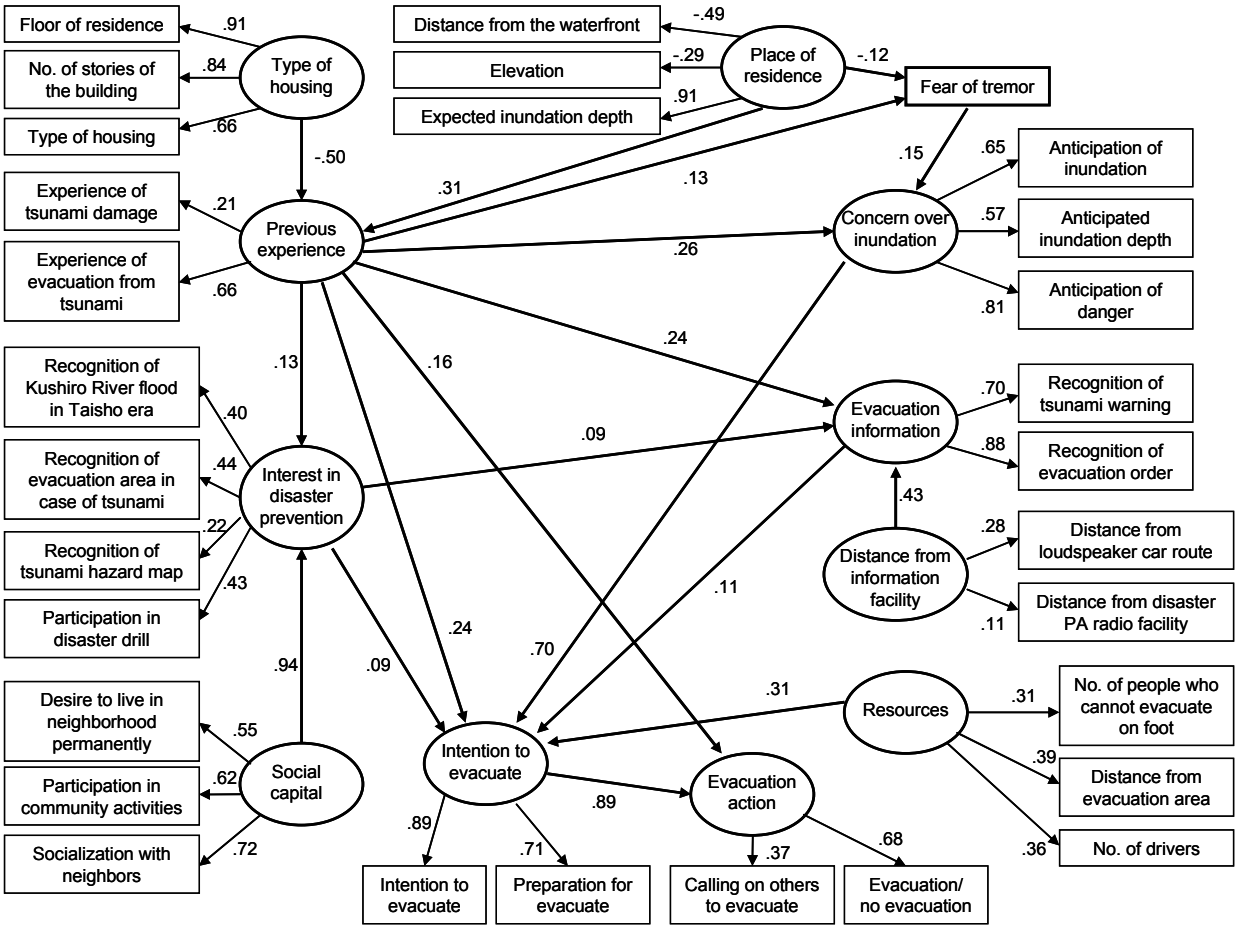

Fig.9 Final Model (Standard Solutions: GFI = 0.797; AGFI = 0.756; RMSEA = 0.059)