Behavioral Analysis of Homebound Public Transport Users During Downpour Conditions

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Abstract: A downpour disaster that occurred on the evening of September 11, 2000 seriously damaged the traffic network in Nagoya city. It also created many problems in traffic management and information services. In this study, we explored the return-home behavior of people during disasters; in particular, we analyzed individual behavior and awareness of disaster prevention in a future downpour among public transportation users through a questionnaire survey. The subjects of the survey were mainly people who travel on foot and/or public transportation users. The results showed that many people were obliged to change their destination due to the suspension of railroad services or to return home on foot. We show that we can control reckless journeys of homebound citizens during disasters, and thus, ensure their safety.

Keywords: Disaster prevention planning, Returning-home behavior, Traffic management

1. INTRODUCTION

The downpour disaster in the Tokai district (hereafter called “Tokai downpour”) in central Japan occurred between 17:00 on September 11th and 04:00 September 12th 2000. A record total precipitation of 500 mm, with 93 mm in a single peak hour, was recorded during this downpour, as shown in Figure 1. This downpour seriously damaged the traffic network in Nagoya city, and posed problems for many citizens trying to return home; also, many houses were flooded. The traffic network in Tokai district was severely affected because the peak hour of the downpour coincided with the rush hour of traffic at around 18:00 on Sept. 11th and many roads were closed. Public transportation services became inoperable due to the continuous heavy rainfall and flooding of the roads. As a result, many problems resulting from the downpour disaster were highlighted, especially from the perspective of transportation confusion, such as the clarification of return-home behavior, the means of support for people experiencing difficulties on the way home, and countermeasures against the confusion on public transport and road traffic during downpour disaster.

The aim of this study is to clarify the characteristics of the return-home trip-making behavior of citizens during the Tokai downpour disaster and to discuss preventive planning and measures to be implemented in the case of a future downpour on the same scale as the Tokai downpour (hereafter called “Future downpour”). These disaster prevention planning measures are based on several statistical analyses. Our research zones are Tokai city (population: 104,339) and Obu city (population: 80,262), which are located near Nagoya city (population: 2.2 million people), as shown in Figure 2. We conducted our questionnaire survey among residents of Tokai and Obu, as shown in Table 1 because these cities have many
commuters who use trains to travel to Nagoya city, and Tokai and Obu, which received the heaviest hourly rainfall during the Tokai downpour.

Figure 1. Changes in hourly precipitation in the Tokai downpour

Figure 2. Areas under study

Table 1. Outline of the questionnaire

<table>
<thead>
<tr>
<th>Distribution area</th>
<th>Distribution method</th>
<th>Collection method</th>
<th>Number of distribution</th>
<th>Number of collection</th>
<th>Collection rate</th>
</tr>
</thead>
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<td>i  Tokai city &amp; Obu city</td>
<td>posting</td>
<td>mailing</td>
<td>1,500</td>
<td>199</td>
<td>19%</td>
</tr>
<tr>
<td>ii High schools in Tokai city</td>
<td>direct</td>
<td>direct</td>
<td>50</td>
<td>33</td>
<td>66%</td>
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We obtained and analyzed data regarding pedestrians and/or public transportation users (hereafter called “foot/public users”) and the two-wheeled vehicle and automobile users (hereafter called “vehicle users”). However, in this analysis, it was the foot/public users who faced more severe difficulties than the vehicle users have been focused on.

2. LITERATURE REVIEW

A lot of researches on evacuation planning or disaster prevention measures for natural disasters in Japan have been done from various viewpoints through behavioral analysis of victims, among others. Through a model analysis based on acquired data from a panel research Fujii et al. (1997) showed that the Great Hanshin-Awaji Earthquake had a large effect on the traffic behavior of citizens. Wakabayashi et al. (1999), by using disaggregates analysis,
showed the importance of considering maximum travel time in selecting transportation means during disasters. Horikiri et al. (2000) clarified the actual situation of affected residents after the Great Hanshin-Awaji Earthquake by building the refuge action model through a discriminant analysis. Although these researches are very interesting since they analyzed the traffic situation at the time of the disaster in each area, they made no reference to the homebound behavior of metropolis residents at the time of the downpour disaster.

This study used a questionnaire survey for travelers affected by the Tokai downpour in order to grasp the actual transportation conditions and the extent to which their experience would influence their preparation for a future downpour. It also examined preventive measures for future disasters through analytic tools such as a chi-square test and a structural equation modeling.

3. OUTLINE OF THE QUESTIONNAIRE SURVEY

The questionnaire survey was administered among residents who lived in Tokai and Obu in 2005 and among those who returned home mainly by foot/public transportation during the Tokai downpour. The outline of the questionnaire is presented in Table 1. The main survey items are: (1) Individual attributes, activities, and circumstances during the downpour; (2) details of return-home modes information, and behavior, and (3) level of awareness and preparation for a future downpour.

In order to generate credible data, we eliminated answers that had missing values. We used 207 samples that include both foot/public users (N =101: bicycle users included) and vehicle users (N =106). It must also be mentioned that these data are sufficiently reliable because 85% of our respondents answered “correct” and “almost correct” to the question asking whether their answers regarding their behaviors were exact or not.

4. EVALUATION ANALYSIS OF THE BEHAVIOR OF RETURNING HOME DURING THE TOKAI DOWNPOUR

This research analyzes and evaluates the characteristics of the returning home behavior in the Tokai downpour by using the results of a questionnaire survey.

4.1 Analysis of Characteristics of Return-Home in the Tokai Downpour

We analyzed the characteristics of return-home behavior during the Tokai downpour by using questionnaire data which included origin-destination data, travel time required to return home, experiences of flood damage on the way home, and questions regarding people’s concerns about their safety, etc.

Figure 3 shows the origins of return-home travel during the Tokai downpour. Since the public transport from Nagoya and the surrounding areas of Tokai/Obu were normally quite convenient, 76% of foot/public users departed from Nagoya and the area beyond it. On the other hand, since vehicle traffic was quite accessible in the Chita peninsula, including Tokai/Obu, 65% of the vehicle users departed from the Chita peninsula.

Figure 4 shows the places where the respondents stayed overnight until the next morning (hereafter called “place stayed”). Ninety-five percent (95%) of vehicle users were able to return to their homes even though they changed their usual route or had to drive cautiously on
flooded roads because most vehicle users lived and worked near Tokai/Obu and the distance of their return commute was comparatively short.

Figure 5 shows the return-home travel time for each transportation mode. It turns out that it took much longer than usual for both users of both modes to return home, since the usual average return-home travel time of foot/public users is about 45 min, and that of vehicle users is about 25 min.

Figure 6 shows a scatter diagram of travel time and departure time for each respondent. Although many respondents left their workplace around 18:00, which was the peak hour of the downpour, their arrival times were dispersed; that is, some respondents arrived at their destination comparatively early, while others arrived late at night.

Figure 7 shows the scatter diagram of travel time and arrival time for each respondent. If we focus on respondents whose arrival times were around 0:00 (or 24:00) at night, we can see that some respondents who left around 18:00, which was the peak of the downpour, arrived at their destination after a long travel time, while others who left after the rain diminished in intensity, arrived at their destination after a comparatively short travel time.

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**Figure 3. Origins of return-home travel during the Tokai downpour**

**Figure 4. Places where respondents stayed overnight until the next morning during the Tokai downpour**

**Figure 5. Return-home travel time, by each transportation mode**
In addition, we see that many respondents who returned home by foot/public transportation arrived at their destination as late as 24:00, even after the public transportation stopped at approximately 18:00; this was because they were picked up by their families, or they changed their destination. On the other hand, some other respondents finally arrived at their destination around dawn the next day. This was because they tried to force themselves to return home, and stayed in a station waiting for the restoration of the train service, or tried to walk a very long distance to their home.

Figure 8 shows the maximum flood water depth that respondents experienced on the way home during the Tokai downpour, for each transportation mode. Although many vehicle users scarcely suffered any trouble due to flooding because they returned home comparatively early, 57% of foot/public users encountered flooding around their home area.

Figure 9 shows the flooded areas covered by respondents on their way home, categorized by the maximum depth of flood water. It is found that the higher the maximum flooded depth, the longer the distance they were flooded on their way home.

Figure 10 shows the perception of danger that respondents felt on their way home for each transportation mode.
maximum flood depth. Since such replies as “boundary of road was indistinct,” “likely to fall in the waterway,” and “likely to be washed away by a flood,” increased when the maximum depth of water exceeded 20cm, situations in which the water depth exceeded 20cm were perceived as very dangerous.

![Figure 9](image)

**Figure 9.** Flooded distance that respondents covered on the way home during the downpour, categorized by maximum depth of flood water

![Figure 10](image)

**Figure 10.** Perception of danger that respondents felt on their way home for each maximum flood depth

### 4.2 Evaluation Analysis of Return-Home Behavior During the Tokai Downpour

Figure 11 shows the respondents’ self-evaluation of their return-home behavior. Since many foot/public users were affected by the torrential rain, as shown in the results in 4.1, they regretted their behavior, with thoughts such as, “I should have departed earlier.” On the other hand, since vehicle users had little trouble on their return home in the downpour, many of them evaluated their behavior saying, “My behavior was proper, with no problem.”

We then clarified the factors that split their evaluations of return-home behavior, through the analysis of quantification theory type II. In this study, “My behavior was proper, with no problem” in the evaluation criteria in Figure 11, is regarded as “Had no problems,” and the other evaluation criteria in Figure 11 are considered as, “Had problems” These were the two categories used in the analysis.

Figure 12 shows the category scores of the result of quantification theory type II. The
negative value of the X-axis in the figure means “Had no problems,” and the positive value means “Had problems.” In addition, since the hitting ratio of this analysis was 77% in the analysis of various variables, it can be said that the accuracy of this model is fairly good.

Figure 11. Respondents’ self-evaluation of their return-home behavior

Figure 12. Category scores of the result of quantification theory type II

The items “Stay place was station,” “Travel time was more than 120 min,” and “Departure time was after 20:00” received high scores in the positive direction (that is “Had problems”), where the “Stay place” is the place mentioned in Figure 4. However, the items “Travel time was less than 60 min,” and “Stay place was except a station or a house” received high scores in the negative direction (that is “Had no problems”).

This result indicates that it became a physical and mental burden for respondents to have traveled for more than 120 min to return home or stay in the station. Here, “Stay place was their house” received a score near 0 because some respondents could return home with no problem, while others had more severe problems getting home.

Moreover, respondents who departed after 20:00, which was more than 2 h later than the
peak of the downpour and the beginning of suspended train service, tended to encounter difficult situations such as no lodging facilities. Results therefore indicated that they evaluated their behavior as “Had problems.” On the other hand, since the respondents who departed before 18:00 returned home after a short travel time, or changed their destination to one offering comfort and accommodations (such as their companies, an acquaintance's house, etc.), had few problems, our results indicated that they evaluated their behaviors as “Had no problems.”

As mentioned above, when the travel time is likely to become very long due to the suspension of train service in a downpour, ensuring that there were accommodations near commuters’ place of origin, and commuters were not trying to return home forcibly, these conditions brought about a high possibility of the result “Had no problems”.

5. ANALYSIS OF THE RELATIONSHIP BETWEEN THE EXPERIENCE DURING THE TOKAI DOWNPOUR AND PEOPLE’S AWARENESS OF DISASTER PREVENTION IN A FUTURE DOWNPOUR

The questionnaire asked about new awareness respondents had towards their return-home behavior in a Future downpour, after asking the details of their behavior in the Tokai downpour. This section analyzes the awareness of disaster prevention in a Future downpour among those who had various experiences during the Tokai downpour.

5.1 Awareness of Disaster Prevention in a Future Downpour

Figure 13 shows the awareness of disaster prevention in return-home behavior in a Future downpour. Since many respondents regretted their return-home behavior in the Tokai downpour, as shown in Figure 11, majority of respondents answered, “I will return home a little earlier” when a Future downpour takes place, and about 90% of respondents would make some preparation for their return-home behavior during a Future downpour.

5.2 Awareness of Return-Home Behavior in a Future Downpour

Figure 14 shows the trigger information that would inspire respondents to change their usual return-home behavior, as shown in Figure 13. In addition, “No change” in the figure means that no matter what information they may have, they will not change their usual behavior. Among respondents trying to change their behavior, 67% of foot/public users emphasized the suspension of train service, and 82% of vehicle users gave importance to water-covered roads.

Figure 15 shows the return-home behavior that would be changed in response to the trigger information in Figure 14. In Figure 15, we see that 66% of the foot/public users who said they would change their return-home behavior if they received trigger information, answered “I will stay in an accommodation other than my house.” However, only 41% of the vehicle users answered, “I will stay in an accommodation other than my house,” since they had only a short distance to travel to return home.

Figure 16 shows the time needed for advance notice by respondents to make decisions to change their return-home behavior. Results in the figure indicate that the foot/public users feel that they need information earlier than vehicle users. Also, if the trigger information were given more than half an hour earlier than the disaster, the majority of respondents would change their return-home behavior, as shown in Figure 15.
Figure 13. Awareness of disaster prevention in return-home behavior for a future downpour

Figure 14. Trigger information that would make respondents change their usual return-home behavior

Figure 15. Return-home behavior that would be changed in response to the trigger information in Figure 14

5.3 Information Services During a Downpour Disaster

The Disaster Emergency Message Dial Service and Disaster Message Board Service have been set up to check upon the immediate safety of disaster victims, which is not otherwise possible due to congestion of the telephone network and the Internet during a large-scale disaster in Japan.
Figure 16. The time needed for advance notice required by respondents in order to change return-home decisions

Figure 17 shows respondents’ level of understanding of both services. Although around 50% of respondents know about the Disaster Message Board Service, and more than 80% know about the Disaster Emergency Message Dial, less than 30% of respondents definitely knew how to access each service. For this reason, both services may be unable to work optimally at the time of a large-scale disaster.

In addition, there are opportunities for people to experience these services one day each month, and during a disaster prevention week, so that many citizens may be educated how to use both services.

Respondents familiar with either the Disaster Emergency Message Dial Service or the Disaster Message Board Service were also asked whether they know how to practically access the service, as shown in Figure 18. Results indicated that respondents’ practical understanding of both services is very low, with almost 80% of the respondents replying, “I don’t have experience in using.”

In summary, although it became clear that few respondents understood how to use these information services, it is important to raise the level of understanding of these services through various promotional activities. This would enable citizens to understand how to access these services so that they could serve a positive function during a large-scale disaster.
5.4 Practical Use of Information Services and Return-Home Behavior

After a preliminary explanation on the use of the two information services, the questionnaire asked respondents whether they would use both services during a future downpour. Figure 19 shows respondents’ intention in this regard. About 45% of the respondents answered, “I will use”, and about 55% answered “I won’t use” or “I don’t decide whether to use or not.”

The next question was on whether using both services would have a large impact on their return-home behavior during Future downpour. Figure 20 shows the results in this regard. About 50% of the respondents answered, “I will be influenced” or “I will be influenced not a little.”

Finally, respondents who acknowledged their use of both services were asked whether their return-home behavior would be influenced by the services, as shown in Figure 21. About 80% of the respondents answered, “If I am assured of the safety of my family, I will not return forcibly,” “If I can convey my well being to my family, I will stay in other safe places or return forcibly,” or “I will return home immediately.”
later,” and “I can communicate my location, I will not move forcibly.” These results indicate that, in the event of a Future downpour, many respondents who made use of both services would not try to force themselves to return home.

5.5 Influence Analysis on the Awareness of Return-Home Behavior and of Preparation for a Future Downpour

In this section, we perform a chi-square test and a structural equation modeling in order to clarify the relationships among the experience of return-home behavior during the Tokai downpour, the awareness of disaster prevention in a Future downpour, and concern about information services at the time of a disaster, which were discussed using a tabulated analysis in the previous section.

5.5.1 Chi-square Test Analysis

First, Figure 22 shows the result of the relationship between respondents’ travel time returning home in the Tokai downpour, and their behavior in a Future downpour. We used 120 min of return-home travel time as the basis for the analysis, because the average travel time in the Tokai downpour was 115.6 min. The behavior data for a future downpour were divided into two classes by using the data from the Tokai downpour.
Since the null hypothesis “Both groups don’t have relevance” was rejected as a result of the Chi-square test, the relationship between travel time in the Tokai downpour and respondents’ behavior in a future downpour is statistically significant. That is to say, respondents who experienced a long return-home travel time in the Tokai downpour intend to go home early at the time of a future downpour.

![Figure 23](image_url)

**Figure 23.** Verified results of the relationship between where respondents stayed during the Tokai downpour and where they would stay during a future downpour

Second, Figure 23 shows the verified results of the relationship between where respondents stayed in the Tokai downpour, and where they would stay in a Future downpour if they received the information presented in Figure 14, obtained through the chi-square test as stated above. Two alternative accommodations were available, namely, their home and a place other than their home.

Since the null hypothesis “Both groups do not have relevance” was rejected as a result of the test, it turned out that respondents who returned home in severe circumstances during the Tokai downpour would not try to return home forcibly in a future downpour, but would choose some place other than their home.

Third, Figure 24 shows the relationship between respondents’ degree of regret over their return-home behavior during the Tokai downpour, and the advance notice they would need (see Figure 14) to change their return-home behavior in a Future downpour. In this figure, “Without regret” means the items “My behavior was proper, with no problem” or “My behavior was proper, but created a problem” as shown in Figure 11. And “With regret” means the other items as shown in Figure 11.

Results of the chi-square test revealed that the relationship in Figure 24 is also statistically significant. Respondents who regretted their return-home behavior during the Tokai downpour desired early information services in a future downpour so they could effectively choose their return-home behavior.

### 5.5.2 Structural equation modeling analysis

In this section, a structural equation modeling is performed using Amos, the software tool offered by SPSS. The objective is to clarify the relationships among three factors, namely, (1) the experience of returning home in the Tokai downpour, (2) the awareness of disaster prevention in a Future downpour, and (3) concern about information services at the time of disaster.

Table 2 shows the latent variables and explains the variables of the model that was adopted in which the variables were rearranged. Figure 25 presents the results in a structural model, which supplements the observed variables in Table 2. The definition “Feeling problems with their return-home behavior” in this table, is the same as “Had problems” as defined in Figure
11. The definition of “Feeling regrets over their return-home behavior” is the same as “With regret” as defined in Figure 24. In addition, the accuracy of this model is considered better because the GFI (Goodness of Fit Index) was 0.909 and the AGFI (Adjusted Goodness of Fit Index) was 0.871. The number of data samples used in this model was 120 due to the removal of deficit values.

![Figure 24. Relationship between respondents’ degree of regret over their return-home behavior in the Tokai downpour, and the advance notice they would need in order to change their return-home behavior in a Future downpour](image)

<table>
<thead>
<tr>
<th>Table 2. Latent variables and explanation of variables in the model</th>
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<tr>
<td><strong>Latent variables</strong></td>
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<tr>
<td>Difficulty on return-home</td>
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</tr>
<tr>
<td>Influenced by train suspension</td>
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<td>Reflection consciousness to return home behavior</td>
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<td>Return-home behavior at the time of a Future downpour</td>
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<td>Concern about Disaster Emergency Message Dial Service and Disaster Message Board Service</td>
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“Difficulty on return-home” of a latent variable had a strong relationship with the observed variables of “Travel time was more than 240 min” and “Arrival time was after 24:00” in the figure. This reveals that respondents who traveled for a long time returning home or arrived at their accommodations around dawn the next day, strongly felt “Difficulty on return-home”. Moreover, since “Being influenced by train suspension” of a latent variable has a strong correlation with the observed variables of “Usual return-home mode is foot/public transportation” or “The origin of return-home was Nagoya”, this indicates that respondents who returned from Nagoya in the Tokai downpour were strongly influenced by the suspension of train service.

When “Difficulty on return-home” and “Being influenced by train suspension” as the latent variables was integrated and correlated with “Reflection on return-home behavior,” it is found that the variable has a strong relationship with “Feeling problems with their return-
home behavior” and “Feeling regret over their return-home behavior.” This means that respondents who had difficulty on their return home deeply regretted and were dissatisfied with their behavior in the Tokai downpour.

The figure also shows that respondents who had difficulty with their return-home behavior in the Tokai downpour will have greater awareness of their behavior during a Future downpour. This could lead to actions such as trying to change their return-home behavior if the trigger information were promptly given, or returning home early to avoid the strong, dangerous effects of the downpour. It is further revealed that respondents were also highly concerned about the information services in such areas, specifically in learning how to use the Disaster Emergency Message Dial Service and Disaster Message Board Service, or experimenting with the use of the message services, among others.

In summary, the results showed that both the influence of the suspension of train service and the awareness of return-home behavior in the past downpour, could lead to improvements in disaster prevention awareness in a Future downpour. This indicates that the various efforts to mitigate and prevent the damage of disaster, such as sophisticated information services could be effectively promoted by informing and reminding people of the difficult experience of the past disaster. However, since it is difficult to make all the citizens act safely at the time of a Future downpour only by developing informational service, it is necessary to reinforce the effort using complementary measures such as the construction of an urgent rest facility.

6. CONCLUSIONS

This study has clarified the characteristics of return-home trip-making behavior during the Tokai downpour disaster through the analysis of mainly foot/public transportation users. It has also discussed preventive measures to relieve the difficulty of returning home in a Future downpour, as part of disaster prevention planning. The conclusions of this study can be summarized as follows:
(1) Through the analysis of return-home behavior in the Tokai downpour by using the quantification theory type II, it was revealed that respondents who stayed in the station all night, traveled more than 120 min in the downpour, or departed after 20:00 in difficult circumstances, evaluated their experience as “Had problems.” On the other hand, respondents who departed before 18:00, returned home after a short travel time, or changed their destination to available comfortable accommodations (such as their companies, etc.), evaluated their experience as “Had no problems”.

(2) The result of a chi-square test and a structural equation modeling revealed that respondents who had difficulty with their return-home experience in the Tokai downpour were quite concerned about their return-home trip-making behavior in the event of a Future downpour, and were also interested in effective informational services. This indicates that various efforts to mitigate and prevent disaster damage, such as sophisticated information services could be effectively promoted by informing and reminding people of the difficult experience of the past disaster.

REFERENCES

