Analysis of return-home behaviors and suitable information for public transport users during downpour disasters

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Abstract

The downpour disaster in the Nagoya metropolitan area in central Japan started at approximately 5:00 pm local time on September 11th, 2000 and lasted until approximately 4:00 am the following day. This downpour seriously damaged the traffic network in Nagoya. During the disaster, there were many citizens who stayed in stations all night long on the way home, many who traveled for more than 240 minutes through the downpour, and many who stayed in safe places such as their offices and tried to obtain suitable traffic information. The aims of this study were to clarify the characteristics of the homebound trips during the downpour, and to develop departure behavior models for the decision as to whether to return home or to stay in a safe place in the event of some future impending downpour disaster. From the analysis, it was shown that civic officials can help to prevent reckless decision-making on the parts of the citizens during a disaster by providing them with suitable information.

Keywords: return-home behavior, disaster, transportation measures.

1 Introduction

The downpour disaster in the Tokai area (hereafter called the “Tokai downpour disaster”) in central Japan occurred between approximately 5:00 pm local time on September 11th, 2000, and approximately 4:00 am the next day. A total precipitation of 500 mm, with 93 mm falling during a single peak hour, was recorded during this disaster (as shown in Figure 1). This downpour seriously damaged the traffic network in Nagoya city, and caused problems for many citizens trying to return home. The traffic network in this area was severely affected because the peak hour of the downpour coincided with the rush hour of
traffic at around 6:00 pm on the 11th, and many roads were closed due to flooding. Public transportation services became inoperable due to the continuous heavy rainfall. During the disaster, there were many citizens who stayed in stations all night on the way home, traveled more than 240 min through the downpour, or stayed in safe places such as their offices while awaiting suitable traffic information.

As a result, many issues were highlighted, such as the need to clarify return-home behavior, the means of supporting people experiencing difficulties on their way home, and the question of what countermeasures can be taken against confusion on public transport and in road traffic during downpour disasters.

The aims of this study were twofold. The first aim was to clarify the characteristics of return-home behavior during the Tokai downpour, including such aspects as the travel time for citizens returning home and where people stayed overnight. The second was to develop departure behavior models for the decision as to whether to return home or stay in a safe place, in the event of a future impending downpour disaster.

2 Outline of survey

Our research zones were the cities of Tokai (population: 104,339) and Obu (population: 80,262), which are both located near the city of Nagoya (population: 2.2 million people) (as shown in Figure 2). We conducted our questionnaire survey of residents in Tokai and Obu, because these cities have many commuters who use trains to travel to Nagoya, and because Tokai and Obu received the heaviest hourly rainfall during the Tokai downpour disaster.

Figure 1: Hourly precipitation during the Tokai downpour disaster.

Figure 2: Areas under study.
We obtained the data regarding pedestrians and/or public transportation users (hereafter called “public users”) and those regarding two-wheeled vehicle or automobile users (hereafter called “vehicle users”). However, in this analysis, the public users, who faced more severe difficulties than the vehicle users, have been focused on.

The survey was conducted in 2005, among residents of Tokai and Obu who returned home mainly by public transportation during the Tokai downpour. The main survey items were: (1) Individual attributes, activities, and circumstances during the Tokai downpour; (2) details of return-home methods, information, and behavior, and (3) level of awareness and preparation for a future downpour.

### 3 Analysis of the characteristics of return-home behavior during the Tokai downpour disaster

We analyzed the characteristics of return-home behavior during the Tokai downpour disaster using the questionnaire data.

Figure 3 shows the places where the respondents stayed overnight until the next morning. Approximately 50% of public users were not able to return to their home.

Figure 4 shows the travel time for return-home journeys during the disaster. It turns out that it took much longer than usual for public users to return home, since the usual average travel time for a return-home journey is approximately 45 min.

![Figure 3: Places where respondents stayed overnight until the next morning during the Tokai downpour.](image)

![Figure 4: Return-home travel times during the Tokai downpour.](image)
4 Departure behavior models in the event of an impending downpour

The analysis in Section 3 showed that many subjects who returned home using public transport during the Tokai downpour experienced such difficulties in returning home that they were forced to stay overnight at stations. They consequently became more aware of the potential occurrence of downpours, and thus more cautious in making the decision about returning home or planning for sufficient communication. In other words, in the event of an impending downpour, the decision to either “return home” or “not return home while staying in a safe place and making efforts at better communication” is one that strongly impacts the extent to which they experience danger, frustration, or regret. As a result, their decision may affect city disaster prevention and disaster reduction plans on a large scale.

Consequently, we limited the scope of our analysis to those who encountered transportation difficulties in returning home by public transport in the study area, and constructed departure behavior models in the event of future impending downpours, using logistic regression analysis to enable a detailed analysis and consideration of the factors impacting their decision and magnitude.

4.1 The construction of departure behavior models for returning home in the event of an impending downpour using logistic regression analysis

The objective variable for the departure behavior model using logistic regression analysis adopted a dummy variable of choice whether to return home or not under an impending downpour disaster.

The subjects were asked what information could change their typical behavior regarding returning home if they knew that a disaster was impending (their responses are shown in Figure 5). Figure 6 shows how their behaviors would be altered as a result of receiving such information. We assumed that the information exerted an impact on subjects’ behavior regarding the decision to return home, and defined their choice accordingly (as shown in Figure 6), “Stay over at a place other than home” was defined as “Choice 1: To not return home,” and the dummy variable was set to 1. “Return home by calling a family member for a ride,” “Return home by taxi,” “Return home even if it requires walking,” “Return home provided that the distance to walk is () m or less,” and “Other (return home by other means)” were defined as “Choice 2: To return home,” and the dummy variable was set to 0.

The logistic regression models were configured based on the choices of the dependent variable outlined above. Individual attributes, such as having experience with disaster, typical behavior regarding returning home, and having an awareness of impending disaster, were used as explanatory variables. There were 85 pieces of data.

Table 1 shows three departure behavior models in relation to returning home, which were constructed by defining different variables. Each of the models demonstrated comparatively high accuracy and likelihood ratios, and since
almost all the explanatory variables reached 5% significance, we determined that they had a high level of explanatory ability.

Figure 5: Information changing commuters’ typical behaviour regarding returning home under the disaster.

Figure 6: The consequently altered behaviours when subjects would get receipt of such information.

Table 1: Departure behavior models regarding returning home in the event of impending torrential rain disaster.
4.2 Consideration of the models

Table 1 shows the three types of model, which were constructed by changing important variables. This section examines each of these models.

a) Model 1 (variables: travel distance, travel time on subway, composition of family)

The main variables in Model 1 were the travel distance between the place of departure (for example, a workplace) and home, travel time on the subway, and family composition, and were simplified as much as possible to use the estimation model of travel demand for returning home in the event of an impending downpour.

The dummy variables pertaining to the travel distance (15 km or more: 1; Other: 0) are considered here.

Figure 7 shows the distance that subjects commute under normal circumstances to work or school, and their choice for returning home in the event of an impending downpour. Approximately 80% of the subjects who had to travel 15 km or more to reach their homes selected “To not return home.” A reason for this was that these people were highly likely to be residents of the cities of Tokai and Obu, commuting regularly to work or school in the Nagoya City area by changing trains at the K. Station, which is approximately 15 km away from both of these cities.

![Figure 7: Travel distance under normal commutes and their choice for returning home in the event of impending torrential rain disaster.](image)

We analyzed similar departure place dummy variables farther from the K. Station; however, using a distance of 15 km to define the dummy variable yielded greater accuracy. We surmised that 15 km was approximately the furthest distance that the subjects were willing to travel to return home in the event of a downpour, once railway or other service was suspended.

Subsequently, we focused on travel time on the subway. In Model 1, we established that the longer the time spent on the subway for a subject’s normal commute, the more likely they were to choose “To not return home.” For
commuters, while the subway is used as transportation to access to inter-city railway stations (mainly the K. Station) when returning from the Nagoya City area to home cities such as Tokai and Obu, railways, including those owned by the JR and Meitetsu companies, are also used as access transport. Other variables such as the railways as access transport were also analyzed. However, the analysis indicated that subway users selected “To not return home” far more often than those using other methods of rail travel as a choice in the event of impending downpour, and as such, we focused on this point in our analysis.

When using the subway to reach a particular transfer station for inter-city railway on the way home, if the subject realizes, at the transfer station, that the inter-city trains are suspended, they must decide whether or not to return to the place of departure (such as their office) or stay in a hotel or elsewhere. If the subway is subsequently suspended and the subject is not able to return to their place of departure, or are unable to acquire a room in a hotel, etc., there is an increased risk that they may have to stay overnight in a station, resulting in subsequent regret and dissatisfaction. Consequently, since this risk increases relative to the length of the journey required on the subway, we determined that the length of travel time spent on the subway resulted in a tendency to choose “To not return home.”

Furthermore, in the free opinion section of the questionnaire, several people indicated a concern regarding the fact that the subway became partially submerged during the Tokai downpour. Therefore, we additionally asked 46 students at our university what their concerns would be with regard to returning home during a sudden downpour when using inter-city railways and the subway.

![Figure 8: Concerns in regard to returning home during sudden torrential rain when using inter-city railways and the subway.](image)

Figure 8: Concerns in regard to returning home during sudden torrential rain when using inter-city railways and the subway.

Figure 8 shows the results of this survey. The questionnaire first asked respondents to select multiple answers with regard to issues that they were concerned about when using inter-city railways (i.e., suspension, flooding, submersion, the difficulty or danger of walking outside during downpour, etc.) These questions were then repeated with regard to the subway. Most users of inter-city railways were concerned about the suspension of train services; by contrast, most subway users were concerned about flooding or submersion. This may be attributed to the fact that inter-city railways in the Nagoya City area feature many parts that are elevated, so flooding is moot, and to the fact that
subway services were not entirely suspended during the Tokai downpour while certain parts of the network became submerged. Based on the above, we assumed that spending a longer travel time on a subway correlated with selecting “to not return home.”

Finally, we focused on the variable of family composition. Figure 9 compares behavior choice based on family composition. Among subjects who lived only with their spouses, and were aged 50 or over, 58% were concerned about their families and selected “To return home,” indicating that in the event of an impending downpour, people with a similar family composition would be highly likely to decide “to return home.”

![Family composition and their choice for returning home in the event of impending torrential rain disaster.](image)

Figure 9: Family composition and their choice for returning home in the event of impending torrential rain disaster.

b) Model 2

Figure 10 shows the maximum flooding depth experienced by subjects returning home on foot during the Tokai downpour in relation to their choice of returning home in the event of an impending downpour. Given a maximum water depth of less than 20 cm, 50% or less of subjects indicated that they would choose “To return home.” However, the proportion of subjects choosing “To not return home” rose significantly at maximum flooding depths greater than 20 cm. This indicated that this variable was effective in Model 2. In the event of an impending downpour, it is clear that information regarding the depth of the standing water and degree of flooding is important in careful decisions to be made by people returning home.

c) Model 3 (addition of a variable for the timing of the acquisition of information)

In Model 3, we added a variable to determine whether the timing of the acquisition of information changed the subjects’ typical behavior with regard to returning home. From the model coefficients and Figure 11, it can be seen that most subjects indicated that the acquisition of this information an hour or more before they departed home would induce them to change their typical behavior, but that changing plans immediately would be difficult if this information was acquired just before departure. When the railways and other transportation services may suspend services during peak commuting hours (between 5 and 6 pm), the provision of information at the earliest possible time enables people to select a wide range of measures.
Therefore, it was found that a distance of 15 km or more between a departure point (for example, a workplace) and home, a lengthy time required on the subway as transportation for access to inter-city railways, a household comprised only of a married couple aged 50 or over, a maximum flooding depth of 20 cm or more when returning home on foot, and the acquisition of information one hour or more prior to departing for home are important factors in preventing people from attempting to return home in apparently difficult circumstances.

These variables were more statistically effective than any of the other variables, and were considered to function as basic information, useful for the proposal of strategies for information provision and coping with people struggling to return home during disasters. In particular, because 80% or more of the subjects who had to travel a distance of 15 km or more to return home indicated that they would not try to return home if appropriate information was provided in a timely manner, the provision of such information could help to avoid unnecessary confusion. Furthermore, we determined that sufficiently
communicating with the residents of large cities on a daily basis regarding the safety of subway networks in times of flooding is necessary.

5 Summary

We constructed departure behavior models for the decision to return home using an objective variable (whether to use public transport, or stay in a safe place without returning home) in the event of impending downpour. We found that travel distance (15 km or farther), time spent on the subway, the timing with which information regarding a sudden downpour was delivered (an hour or more earlier), and other variables were important in influencing people to not attempt to return home. We believe that communicating appropriate information based on an understanding of behavioral attributes before people start their commutes could be effective as a means to reduce the impact of disasters.

References