A Supporting System for Emergency Vehicles Dispatching Planning Under a Disaster Situation

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Abstract. Japan is an earthquake-prone country; however, it is also affected by other types of disasters such as typhoons, floods, volcanoes, and landslides. These disasters cause significantly severe damage in affected areas. During large disaster events, the fire departments of affected areas are expected to bring help to these areas. Unfortunately, the number of emergency vehicles and firefighters are limited. Therefore, if emergency calls are handled in a first-in first-out manner, the ability to respond to all calls is compromised. Thus, in order to consider the priority of calls based on the best strategies, call triage is discussed in this study. Call triage requires a thorough investigation of possible situations; however, as a variety of situations exist, investigation on paper is difficult. This study proposes a support system for emergency vehicle dispatch planning using the best call triage. The effectiveness of the system is verified through subject experiment.

Keywords: Call triage · Fire department · Emergency vehicles dispatching · Earthquake

1 Introduction

Japan is an earthquake-prone country, yet it is also affected by other types of disasters, such as typhoons, floods, volcanoes, and landslides. Furthermore, the occurrence of a Nankai Trough Earthquake and a Tokyo metropolitan earthquake are expected by the Japanese government [1]. If such earthquakes were to occur, Western Japan and Tokyo would be significantly affected. Interest in earthquake countermeasures has been increasing in recent years and the government has begun to take various measures.

When a large-scale disaster occurs, firefighting departments must effectively respond to an enormous amount of call-ins from a vast area. However, in reality, firefighters and emergency vehicles are dispatched in the order that the call-ins are received (first-in first-out; FIFO), and seldom is there a strategic approach for emergency vehicle

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dispatching. However, if firefighters and emergency vehicles are dispatched to each of the call-ins in order, there will be shortage of emergency vehicles and firefighters in that prefecture, making responding to subsequent and more serious cases difficult. To avoid such cases, it is important to get a complete picture of the state of the disaster to dispatch the limited firefighters and vehicles effectively.

A survey conducted on the firefighting head offices in Iwate, Miyagi, and Fukushima prefectures after the Great East Japan Earthquake revealed that more than half of the firefighting head offices did not have an emergency vehicle dispatch plan in order to handle cases where multiple disasters occur simultaneously and there were many call-ins for fire protection and life-saving [2]. The survey also suggested that many of the firefighting head offices recognized the necessity for firefighting strategies and emergency vehicle dispatch plans. One of the most important considerations when designing an effective emergency vehicle dispatch plan is the intensive input of emergency vehicles and firefighters to call-ins of higher priority based on the damage prediction for the area. This type of priority classification of call-ins is called "call triage" or "triage." Triage is defined as a strategy of sorting and allocating aid on the basis of need for or likely benefit from medical treatment [3]. This concept is applied to disaster call-ins by considering the severity and urgency of requests. In the areas affected by the Great East Japan Earthquake, 936 firefighting head offices had triage plans. In sixteen offices, there were cases where triage was required and executed [2]. To ensure that triage is effective, priorities have to be decided among various important factors such as dead or injured persons, firefighting or rescue of buried persons, and firefighting in large dangerous chemical factories or high-density wooden house areas. Since decisions depend on the area, each firefighting head office must decide its own priority strategy considering the characteristics of the area. Although call triage support systems in the medical field have been developed [3], there are few in the field of disaster management.

The decision-making design of a triage strategy and an emergency vehicle dispatch plan require thorough investigation of possible disaster scenarios. A wide variety of possible situations exist, and the evaluation of each triage strategy on paper is difficult. To support firefighting head offices in their design of emergency vehicle dispatch plans, this study proposes a computer simulation based design support system that supports verification of various dispatch strategies by using hazard maps and existing fire department data, in order to solve the problems of lack of available firefighters and emergency vehicles. This system simulates damage in cases of a large-scale disaster based on the earthquakes expected to occur in the area. These assumed damage scenarios are randomly sent out to users as call-ins from citizens, and then the users can consider the dispatch planning of emergency vehicles based on these data and the damage situation and then decide when to dispatch the emergency vehicles and input data to the system. The system simulates the response status in the area damaged by the disaster based on the input data. For example, the system simulates the time required from dispatch of emergency vehicles until patients are transferred to the medical institutions and the time required to put out the blaze. Then, using the simulation results, the system chronologically calculates evaluation data such as the number of sick and injured, time that the fire remained uncontrolled, response rates, number of casualties, and number of injured. In other words, users can not only confirm the damage status of the earthquake and response status visually but also find response rates and the specific number of sick and injured people chronologically on a digital map. Users can assess the response based on the evaluation data calculated. Therefore, users can save the response status of the emergency vehicles to a particular disaster, and compare the data of one strategy with the data of other strategies. Because the proposed system can simulate many strategies and compare various result data, it can help emergency services to create better dispatch strategies if used repeatedly.

In this study, Konan, Shiga prefecture, is considered the target area. We build a prototype system for this area, and then conduct interviews with the firefighting personnel of Konan fire department in Shiga prefecture to evaluate the usability of the proposed system.

2 Related Work

2.1 Development of a Model of the Transportation Time Required to Complete a Transfer to Hospital by the Ambulance System

To calculate a corresponding rate for emergency operations, the emergency lifesaving transportation time is required to be calculated. Kataoka et al. [4] classified this process into five steps from the request for dispatch of emergency services to the arrival at medical institutions in order to grasp the actual situation of emergency lifesaving activities in the present conditions. These steps involve (1) dispatch request, (2) preparation to dispatch, (3) arrival at the site, (4) operation, and (5) transfer to a hospital. They built models to calculate the time required for each step. These models are introduced into this research in order to calculate the time required for each step of operation for selected call-ins.

2.2 Decision Elements of Priority Decision for Dispatch

During the East Japan Great Earthquake, many accidents occurred simultaneously. In deciding the priority of call-ins, the firefighting headquarters chose firefighting teams to be dispatched based on the contents of the received call-ins, taking into consideration the following nine items [2].

(1) Effect on human lives
(2) Degree of urgency of accidents
(3) Scale of accidents
(4) Occurrence point of accidents
(5) Possibility of response by residents
(6) Risk of secondary accidents
(7) Risk of extension of accidents
(8) Severity of injuries to victims
(9) Risk associated with the lapse of time

Our proposed system also considers these items as factors to determine the priority order.

3 System Proposal

Since dynamic disaster situations can change enormously, it is difficult for firefighting planners to form an effective dispatch plan for emergency vehicles and firefighters on paper. There are few systems that support decision-making based on effective priority criteria and planning of effective firefighter dispatch plans in order to respond to the dynamically changing disaster situations. The effectiveness and deficiency of this method are evaluated by simulation of the dispatch of vehicles and firefighters. For the simulation of the dispatch of firefighters, a variety of elements relating to firefighting operations must be modeled, including firefighting facilities, road traffic conditions, collapse situation of buildings, and damage to infrastructure.

First, we clarify the functions required by the system to verify the validity of dispatch planning methods as follows.

(1) The call-ins must be generated rationally and with realism.
(2) The required time from dispatch of ambulances for transporting victims to medical institutions must be calculated rationally.
(3) Progression in the symptoms of victims must be simulated rationally on the basis of transportation time of victims to medical institutions.
(4) The required time from the dispatch of fire engines until their arrival at fire sites must be calculated rationally.
(5) Total operation times must be calculated in order to cope with damage that requires emergency services, such as fires, house collapses, and landslides, on the basis of factors such as the disaster scale and type of house.
(6) Based on (3), (4), and (5), the performance indices such as response rates, waiting time, and death toll must be calculated for each dispatch plan.

The response rate refers to the percentage of dispatched call-ins with respect to total call-ins. The waiting time is the time between the receipt of a call-in and the arrival of an emergency team at the site. A death toll is calculated on the basis of the waiting time of seriously injured persons. When the waiting time of a seriously injured person exceeds sixty minutes, he/she is judged as dead.

This system is a tool for designing a dispatch strategy for emergency vehicles and teams in large-scale disasters by local governments. The system simulates the process of dispatch when the user selects a certain dispatch strategy. Among the six functions to listed in Chapter 3, the functions (1), (2), (3), and (6) are implemented in the prototype system. Figure 1 shows the system configuration.

JavaScript and HTML are used to implement the prototype system on a PC. The Google Maps API is also used to implement the map-based user interface to provide the dispatching process of emergency vehicles and teams.

(1) Event generation unit: All call-ins are generated after the user selects a disaster scenario.
(2) Call-in list unit: When the user presses the “wait button”, a generated call-in is selected in the order of occurrence time and is displayed on the computer screen.

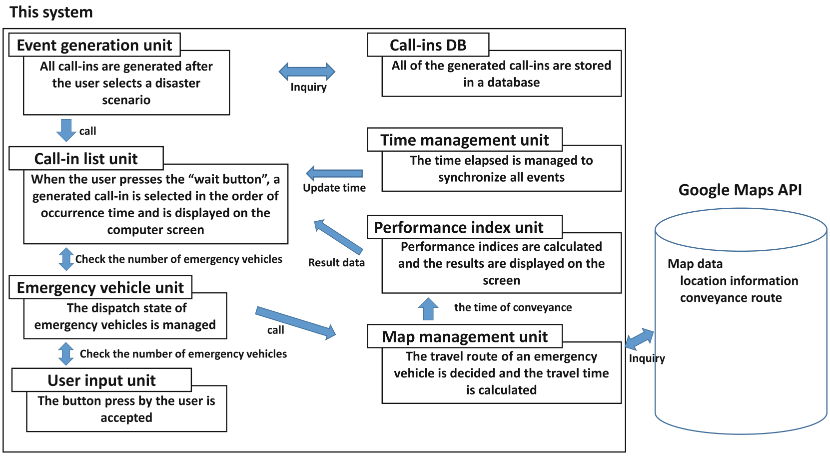

Fig. 1. System configuration diagram

(3) Emergency vehicle unit: The dispatch state of emergency vehicles is managed.
(4) User input unit: The button press by the user is accepted.
(5) Call-ins DB: All of the generated call-ins are stored in a database.
(6) Time management unit: The time elapsed is managed to synchronize all events.
(7) Performance index unit: Performance indices are calculated and the results are displayed on the screen.
(8) Map management unit: The travel route of an emergency vehicle is decided and the travel time is calculated.

At the first step of the simulation, the system generates all call-ins, with the occurrence time and place, according to the scenario selected by the user. Each scenario is formulated on the basis of the damage prediction in the regional disaster prevention plan. When the user presses the "wait button" on the computer screen, a call-in is selected in the order of occurrence time and is displayed on the screen. After the user selects the indicated call-in, an emergency vehicle is selected and dispatched. Then, the time is set forward by the amount of time required for coping with the call calculated by the time management unit. If the user presses the button instead of selecting the indicated call-in, the system selects the next call-in and displays it under the previous call-in on the screen. The user makes this decision (selection of the indicated call-in or press of the button) based on the dispatching strategy. For example, if the user follows the FIFO strategy, the indicated call-in is selected. If the user follows the scenario that gives priority to severe incidents, the user presses the button to confirm if a more severe incident may occur. When the next call-in is listed on the screen, the time is also reset at the time when the call-in occurs. Figure 2 is a screenshot of the system and Fig. 3 shows the flowchart of the event process.

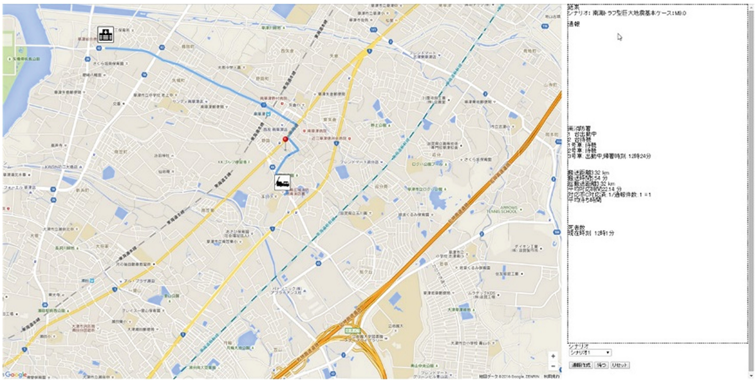

Fig. 2. An example of the screen

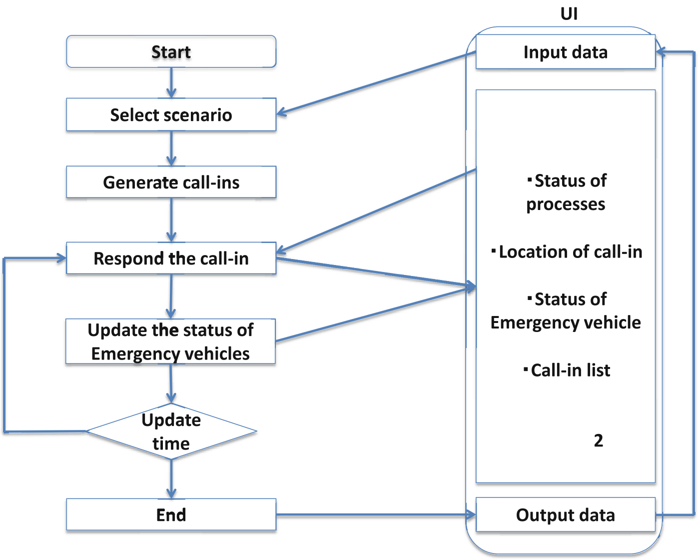

Fig. 3. A flowchart of the event process

4 Evaluation

To validate the efficacy of this system, five specialists in disaster prevention, who are members of Konan Fire Department, Shiga, Japan, performed evaluations. First, the system was explained and demonstrated for thirty minutes. Next, the specialists used the proposed system for five minutes. Following this, the specialists responded to a questionnaire regarding their opinions. The scenario (Table 1) and estimation of earthquake damage (Table 2) that was used for evaluation are given below.

Table 1. Scenario used for validation purposes.

Nankai Trough Earthquake occurred at noon during the summer and its magnitude was 9.0. There are many call-ins from the Konan area.

Table 2. Estimation of earthquake damage used for validation purposes ("—" indicates a number less than 5)

	Kusatsu city	Moriyama city	Ritto city	Yasu city	Total
Maximum seismic intensity	6 lower	6 lower	6 lower	6 lower	
Number of deaths	–	–	–	–	–
Number of injured	35	16	7	27	84

4.1 Specialist Evaluation Results

Five specialists (A–E) validated the efficacy of this system and assessed how realistic the simulation was. The following are the results of the evaluation (Fig. 4) and questionnaires.

(1) Is this system effective for planning the dispatch emergency vehicles during a disaster situation?
(2) Was the simulation close to the real situation?

None of the items received a very positive evaluation.

For "is it close to the actual condition?" we received opinions such as "it would be closer if conditions such as rescue and firefighting activities were added," and "situations in which traffic congestion occurs due to road construction and traffic accidents etc. and hospital acceptance conditions were not taken into account."

For "effectiveness," we received opinions such as "a range of special cases that can occur are required, not just emergency cases," and "if simulations of things that

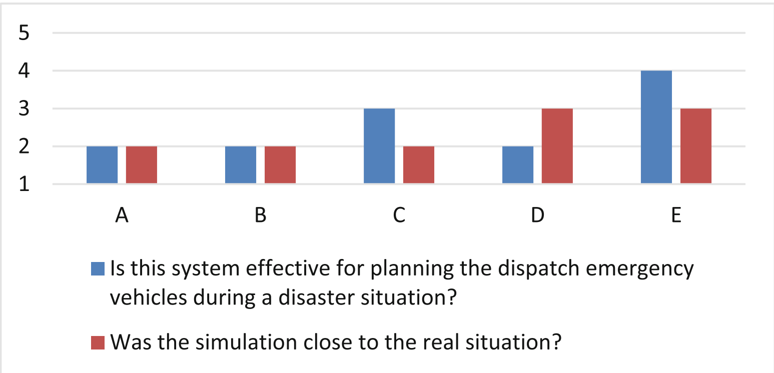

Fig. 4. Results of the evaluation

organizations or young members have not experienced previously are carried out then it is possible to perform activities more effectively." To support examination, disasters that have not yet been experienced and ease of examination need to included.

As all experiment collaborators were experienced persons who have received actual 119 calls, it is concluded that the system is limited from the point of view of sense of reality when compared to real-life situations. As this implementation only considered emergency aid that did not deal with fire and rescue, the difficulty of using the system as an aid in actual disasters, such as the very large landslides that occurred as a result of Typhoon 18 in 2013 was pointed out.

5 Conclusion

The proposed study aims to support planning decisions to carry out effective dispatch of fire brigades by self-governing bodies using triage. This aspect of emergency planning has not been extensively investigated until now. The system allows evaluation through simulation of real situations of disasters and dispatch requests dealt through FIFO or a form of triage. The system was evaluated by fire officials of the Hunan area administration union. The results indicated that, by adding conditions with increased complexity, which have not yet been experienced before by organizations or new members, it was found that activities could be carried out more effectively.

On the other hand, it was identified that further consideration should be given to firefighting or rescue activities, road conditions, and acceptance to hospitals.

Future improvements would include adding conditions that have not yet been experienced by organizations or new members. By adding these conditions, there is not only scope for further investigation but also the possibility of practical usage for training new members.

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