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Study on Road Information Sharing Using Probe Vehicle in Disasters

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Abstract

Road information sharing is vital in disaster response, but it still remains today a significant problem in spite of the recent breakthrough of information and communication technology.

In this study, we overview the present situation and structure problems on road information sharing. Two main problems are as follows: i) how to gather the information about which road can be used and ii) how to share the information among different disaster information systems used in the authorities concerned.

We propose road information sharing using probe vehicle data to solve the first problem. The characteristics and the possible use of the GIS plotted probe vehicle data in past disasters are discussed. The probe vehicle data provide information to decide which road are likely to remain available at the time, and also where the vehicle turned around, that indicates the road might not be available.

The travel time of individual car trips are numerically simulated with and without road information sharing among the cars. The reductions of the travel time depend on numbers of probe cars and road closures. The simulation results indicate that the probe vehicle data can be effectively used to reduce the travel time in a time of disaster, and to gather regional information on available roads.

Keyword: *probe vehicle, road information, information sharing*

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1. Introduction

Sharing traffic and road information is essential for effective disaster response. Despite the recent remarkable progress made in Information and Communication Technology, at present there is no generally accepted solution for this problem.

Here we overview current state and problems in sharing traffic and road closure information. We also propose and evaluate a new method for information sharing on road closure using probe vehicle data. Probe vehicles have been used practically in the transportation field [1] as a means of gathering information, such as speed and direction, from cars now driving.

2. Current state of information sharing during disasters

In this chapter, we overview schemes of road information sharing and contents of information currently used. Most of the existing schemes are limited to major roads.

Ministry of Land, Infrastructure and Transport Government of Japan (MLIT) check damage and availability of roads under the Ministry. Road information is provided through the internet and electric bulletin boards installed above the roads. The tabular information provided in their web site includes road closures and traffic regulation information of major roads.

Japan Road Traffic Information Center (JARTIC) [3] provides information gathering and distribution services delegated from traffic administrators and roads authorities such as the National Police Agency and MLIT. Traffic and road information is widely distributed through radio, television and the internet. Tabular and graphical traffic information provided in their web site includes route name, section and direction, cause and details of traffic regulation.

Vehicle Information and Communication System (VICS) [4] distributes literal and graphical traffic information to in-car navigation system. Drivers can get real-time traffic information, including vehicle speed, travel time, accident, roadwork, speed limit, lane closure and car parks. About 70,000 km out of 330,000 km length of major roads are covered.

3. Problems in sharing traffic and road closure information

Road information of both disaster site and its surrounding areas is required for interregional rescue and backup during disasters. This means that several road administrators are expected to share their road information. We structure road information sharing problems during disasters for road users and administrators through interview investigation.

3.1 Lifeline suppliers and physical distribution companies

1) It is difficult to exactly locate a position from literal road or traffic information.

2) They felt lack of information about road availability and damage severity.
3) They could not get well-timed road information while driving in the disaster site.
4) No special road information for emergency vehicles, which are given priority, is provided.
5) Reliability, update frequency and the last update time of information were not available.
6) Road information sharing and coordinated information providing are required.

3.2 Road administrators

1) Traffic regulation sections can not be exactly located, for their names are not standardized.
2) Regional road information which is required for finding a diversion is not shared.
3) Integrated road information service is not available during disasters.
4) Total length of local roads is so long that the administrator can not patrol in a short time.
5) An information system is required to gather road information from local residents and drivers, and to share and provide it.

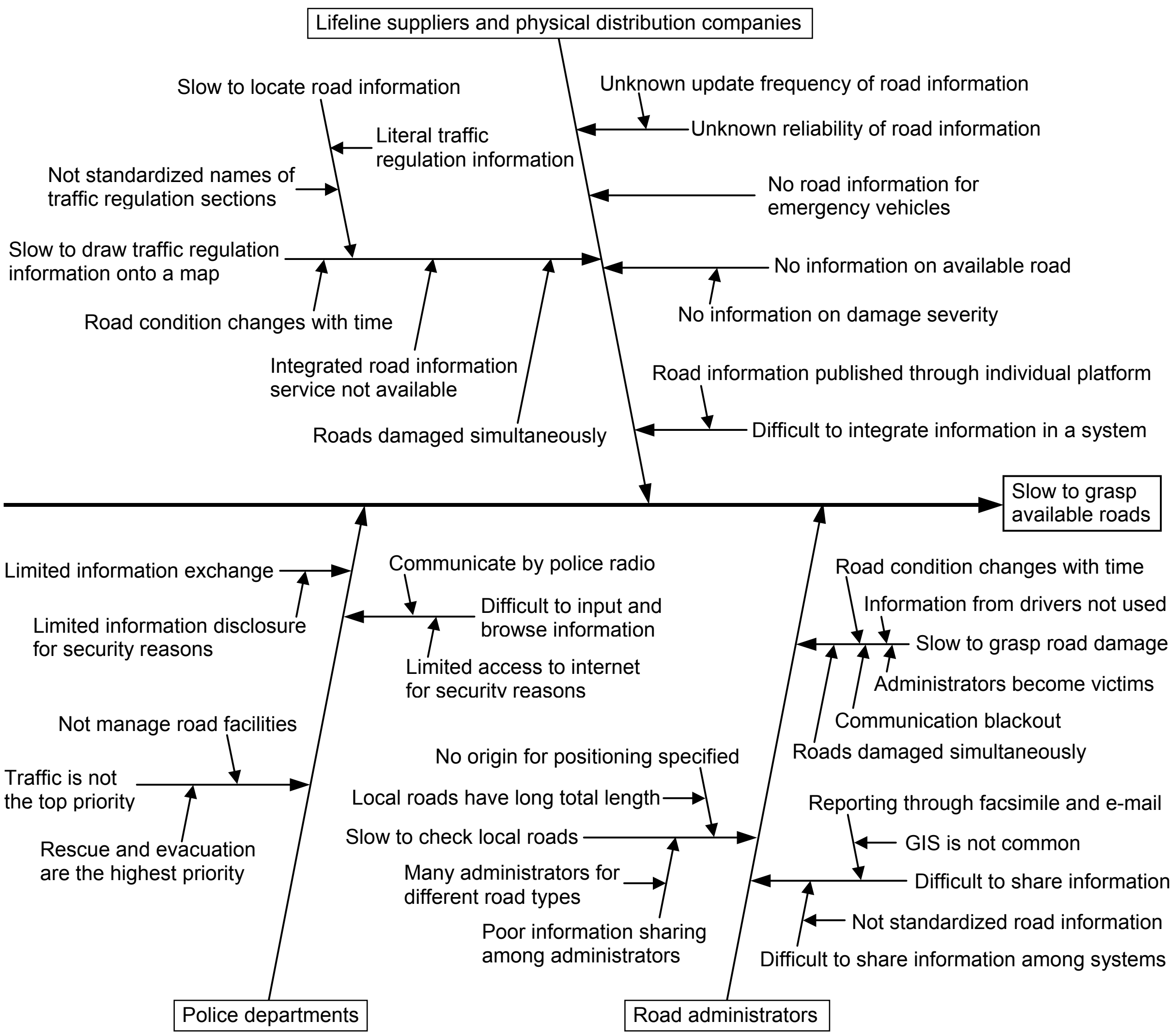

Fig. 1 Cause and effect diagram of road information sharing problems

3.3 Police departments

1) Traffic regulation information is gathered through facsimiles and e-mails whose forms are not standardized. Traffic regulation sections are drawn onto a paper map afterwards.
2) High priorities are rescue operations, second disaster prevention and evacuation guidance for which road information is vital.

Based on these interview results, road information sharing problems are structured in a cause and effect diagram [5] shown in **Fig. 1**. The important points to share road information effectively are as follows: 1) speedy check for road availability, 2) providing prompt access to road information. Sharing probe vehicle data, which is explained in the following section, is proposed to solve the first problem described above.

4. Probe vehicle data and its effectiveness

Information on available roads is vital for effective disaster response, and it can be quickly and directly gathered from probe vehicles. The vehicles record their position (longitude and latitude), bearing, date and time.

4.1 Example of probe vehicle data in a disaster

Fig. 2 shows positions of probe vehicles every six hours from the occurrence of Niigata Chuetsu earthquake, 2004 to the end of the next day. Short red lines mean road closures which started by that time. Some vehicles have their trajectory records inside of the road closure sections. It occurred because the vehicles ran there before closed, or literal information of road closure were interpreted longer than actual length on the map. **Fig. 3** shows a trajectory of a vehicle turned around before road closures.

4.2 Simulation study of probe vehicle data sharing

We study here travel time and status known rate of available roads with and without road information sharing. Status known rate is defined as a ratio of the length of roads at least one probe vehicle passed over the total length of available roads. Road network of Niigata Chuetsu region includes about 7,500 links and its total length is around 4,240 km.

Origin and destination pairs are randomly selected as their linear distances are around 50 km. Average speed of vehicle assumed to be 30 km/h. The vehicles initially take the shortest path to their destinations without road closure information. If they encounter a closed road, they find new shortest path from there to the destination. Road closure information is shared among all the vehicles every five minutes. The probe vehicle data does not actually include

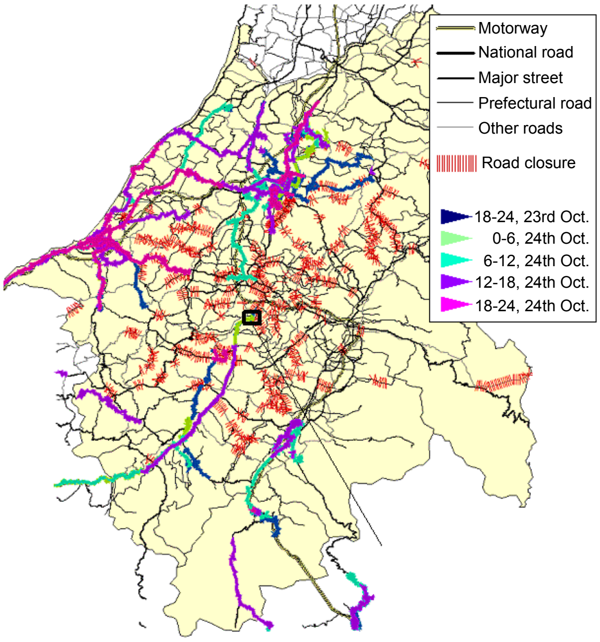

Fig. 2 Probe vehicle trajectories after Niigata Chuetsu earthquake, 2004

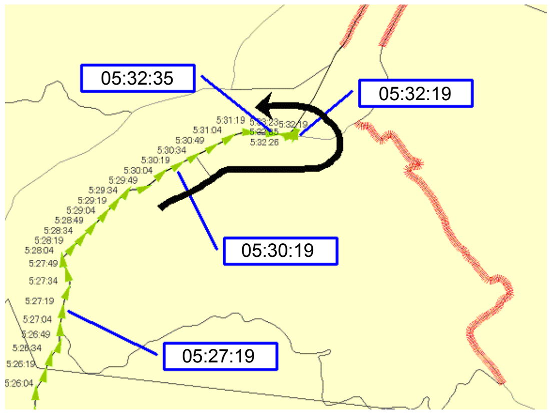

Fig. 3 Trajectory of a car turned around before road closures

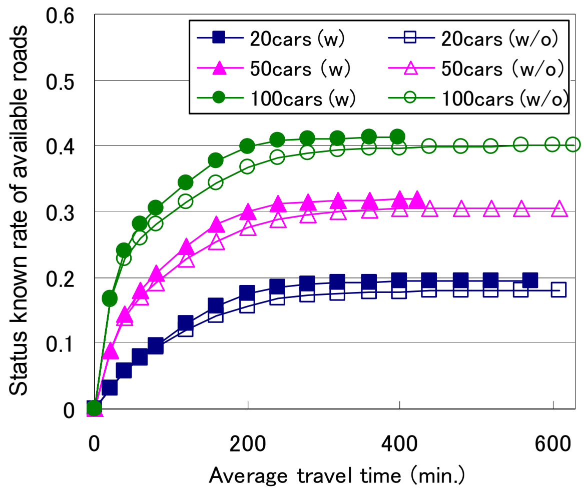

Fig. 4 Time variation of status known rate of available roads (300 closures)

explicit road closure information, but it can be derived from trajectories of vehicles turned around.

Average travel time and status known rate of available roads for 100 cases were simulated numerically with 20, 50, 100 vehicles and with random 100, 200, 300 road closures.

The average travel time and its shortening rate are shown in **Table 1**. The shortening rate is defined as 1- (total travel time with information sharing)/(total travel time without information sharing). Time variation of status known rate with 300 road closures is shown in **Fig. 4**.

Sharing road closure information shortened the maximum and the average travel time in all cases. Even in the case of 300 closures, information sharing among 100 probe cars brings more than 12 % shortening of travel time. The information sharing of road closure reduces the number of trial times of shortest path search. This leads to smaller or larger status known rate compared to that without information sharing, according to road network complexity. In case of the road network of Niigata Chuetsu region, slightly larger status known rates were obtained by road closure information sharing as shown in **Table 2**.

Sharing of probe vehicle data can achieve travel time shortening, as well as road administrators, lifeline suppliers and physical distribution companies can gather the information on the regional available roads of the disaster site.

Table 1 Average travel time and shortening rate of travel time

Num. of road closures	Number of vehicles								
	20			50			100		
	w/o(min)	w(min)	SR(%)	w/o(min)	w(min)	SR(%)	w/o(min)	w(min)	SR(%)
100	156.3	134.0	14.3	167.8	141.1	15.9	161.3	138.9	13.9
200	178.0	174.9	1.7	189.8	170.9	10.0	178.0	155.6	12.6
300	205.4	187.4	8.8	201.4	187.1	7.1	194.9	171.2	12.2

w/o: travel time without information sharing, w: travel time with information sharing, SR: shortening rate

Table 2 Average status known rate of available roads

Number of road closures	Number of vehicles					
	20		50		100	
	w/o(%)	w(%)	w/o(%)	w(%)	w/o(%)	w(%)
100	15.9	16.5	27.6	28.2	36.8	37.2
200	16.9	18.0	29.0	30.0	38.1	38.8
300	18.0	19.4	30.6	31.9	40.0	41.2

w/o: status known rate without information sharing, w: status known rate with information sharing

5. Conclusion

We overviewed problems in sharing traffic and road information during disasters from an interview investigation, and structured them in a cause and effect diagram.

The important points to share road information effectively are as follows: 1) speedy check for road availability, 2) providing prompt access to road information. We proposed probe vehicle data sharing to solve the first problem described above. Actual probe vehicle data in a disaster was introduced and its effectiveness in disaster response was shown.

Numerical simulations show that travel time can be shortened and information on available roads in wide area can be gathered when road information derived from probe vehicle data is shared. The results shows that it is expected to work effectively in a large-scale disaster.

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