Effect of traffic accident on arterial road network

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1. Background

Traffic accidents and congestions have influence on each other. Traffic accidents often cause road closure and lane regulation, which decreases the capacity of the road, and deteriorates the smoothness of traffic flow. On the other hand, traffic congestions cause stop-and-go behavior of vehicles, resulting in rear-end collisions and sideswipe accidents. Most reports on the impact of traffic flow on the occurrence of traffic accidents[1)2)3).] However, there are limited reports on the impact of traffic accidents on traffic flow. One of the studies by Iwasaki[4)] evaluated the congestion lost time due to accidents on an expressway network, but it does not consider the surface arterial streets, which should also be affected due to detours.

Traffic flow data has been mainly relied on road-side sensors, such as ultrasonic detectors on expressway networks. On arterial road networks, the sensor coverage is limited to some major routes, and most of the network is left unobserved. Recently, increasing number of probe vehicles are widespread, which enables network-wide traffic flow observation.

This study proposes a method to evaluate the impact of traffic accidents on traffic flow of arterial road networks by utilizing a nation-wide probe vehicle data.

2. Analysis method

2.1 Overview

This study evaluates the impact of traffic accidents on network-wide traffic states by comparing the network performance indicators after accidents with the ones in normal case. The significance and duration of the impact of accidents depend not only on the severity of the accident but also on the traffic conditions at the time of the accident occurrence. This study evaluates the network performance indicator in hourly basis, and the indicators of normal cases are compared with the ones affected by accidents.

2.2 Relative travel speed as a network performance indicator

This study utilizes a nation-wide probe vehicle data, called ETC2.0. Although the number of equipped vehicles are increasing, they account for only 0.1% of total traffic[5)], and the travel speed from the ETC2.0 vehicles do not always represent the performance of whole network; but it tends to capture the traffic states of particular locations where the equipped vehicles are driving. In order to avoid the effects by the locations of vehicles, this study uses the relative travel speed of the probe vehicle as the network performance indicator. The relative travel speed is the difference between the travel speed of a vehicle i and the average travel speed of the same hour along the vehicle trajectory calculated over the study period as defined by equation (1). The speed of vehicle i is calculated by equation (2). In calculating the average travel speed $\overline{V_i}$, the study road network is divided into 500m-square meshes, and the list of meshes that belong to the trajectory of vehicle i is extracted; the average travel speed is calculated as the harmonic mean of the average travel speed of the meshes in the list, as denoted by equation (3). The average travel speed of each mesh is calculated using equation (4).

$$p_i = v_i - \overline{V_i} \tag{1}$$

p_i : Relative travel speed of vehicle i [km/h]
v_i : Travel speed of vehicle i [km/h]
$\overline{V_i}$: Average travel speed of the same hour over the study period along the trajectory of vehicle i [km/h]

$$v_i = l_i / t_i \tag{2}$$

l_i : Travel distance of vehicle i [km]
t_i : Travel time of vehicle i [h]

$$\overline{V_i} = N_i \Big/ \sum_{j \in A_i} \left(1/V_j^{T_i}\right) \tag{3}$$

$$V_j^T = \sum_{i \in B_j} l_i^j \Big/ \sum_{i \in B_j} t_i^j \tag{4}$$

N_i : Number of meshes along the trajectory of vehicle i
T_i : Hour of travel of vehicle i
V_j^T : Average travel speed of mesh j in hour T [km/h]
l_i^j : Travel distance of vehicle i in mesh j [km]
t_i^j : Travel time of vehicle i in mesh j [h]
A_i : Set of meshes passed by vehicle i
B_j: Set of vehicles traveled in mesh j

2.3 Study network

The study is conducted in the network of 7km-square area of Matsuyama, Japan. The area is divided into 196 of 500m-square meshes.

2.4 Data summary

The study period is 3 years from April 1, 2015 to March 31, 2018, and ETC2.0 probe data and injury accident record are used. The number of accidents is 4,023 over the study period.

3. Result

For each hour from 0AM to 11PM, the relative travel speed of all vehicles that traveled in the study network was calculated. **Figure1** compares the average relative travel speed in case of no accident with the average relative speed at the same hour of accident occurrence, as well as with the average relative speed of one hour after accidents, and two hours after accidents. Analysis of variance was performed for each hour. It is observed that all the colored plots are below the diagonal line, indicating that the average relative travel speed in case of accident occurrence is significantly lower than the one of normal case. This result indicates that the accidents affect the network-wide travel speed up to two hours after the occurrence.

Table1 summarizes the F statistics of the analysis of variance performed for each hour; the hours which are significantly affected by accident occurrence are in the table. For instance, the relative travel speed of 7AM is significantly affected by the accidents occurring not only in the same hour (i.e., 7AM), but also in the past 1 hour (6AM). The results indicate that the travel speed from 7AM to 8PM is affected by the accidents that occurred within past 2 hours. **Figure2** shows the total travel distance and the average speed of each hour in the study network; the figure shows that higher traffic volume and lower average travel speed are observed from 7AM to 8PM. Also, as shown in **Figure1**, since the relative travel speed decreases due to the occurrence of an accident, the travel speed of each vehicle decreases due to the accident during periods of heavy traffic and low average travel speed. It was shown that the network traffic flow status deteriorated.

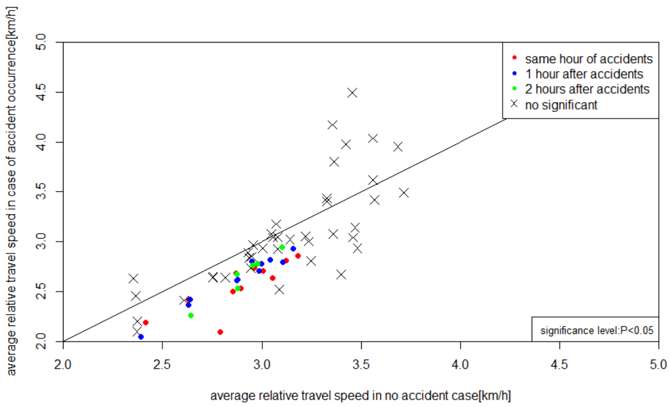

Figure1 Average relative travel speed by accident

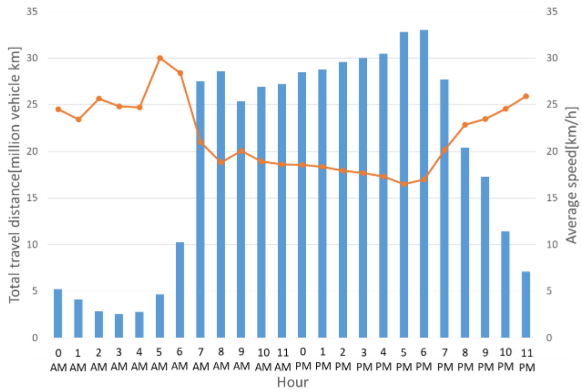

Figure2 Total travel distance and average travel speed of each hour

Table1 F statistics of each hour

Hours	Number of Sample	Accident occurrence		
		Same Hour	1 hour before	2 hours before
3AM	5,080	14.35***	0.27	1.51
7AM	70,100	10.41**	8.44**	0.24
8AM	78,679	140.05***	4.06*	1.87
9AM	70,780	27.29**	49.54***	2.92
10AM	75,275	2.10	17.94*	8.94**
11AM	77,782	19.62***	0.15	5.98*
12PM	82,283	25.01***	9.82**	3.40
13PM	82,005	12.52***	5.27*	7.95**
14PM	84,306	19.90***	11.53***	0.03
15PM	85,767	8.72**	14.89***	10.47**
16PM	87,178	3.40	64.7***	2.22
17PM	93,892	16.47***	21.95***	41.20***
18PM	92,552	46.40***	23.90***	31.20***
19PM	76,396	33.37***	13.01***	1.01
20PM	55,191	0.87	11.95***	0.17

Significance level : P＜0.001 *** P＜0.01 ** P＜0.05 *

4.Conclusion

In this study, using ETC2.0 probe data, a method for analyzing the effect of an accident on traffic flow in a wide area network was developed. As a result of applying this analysis method to the Matsuyama city, it was shown that there are hours in the daytime where the speed decreases due to the accident that occurred one or two hours ago.

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