“A Study on Travel Time Prediction using Cumulative Curves during Incident Occurrence on the Metropolitan Expressway”

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Abstract

We analyze impacts of an incident occurrence on traffic flow on the Metropolitan Expressway as the first step of travel time prediction study during incidents. We show the relation between the actual incident and the data which are available. Using two year traffic detector data and one year accident record on Route 3, we analyze their impacts on traffic flow by plotting cumulative curves along the route. Based upon this study, we plan to eventually propose a travel time prediction method during incident occurrence.

1. Introduction

Now, the Metropolitan Expressway (MEX) is the major highway in the Tokyo metropolitan area, which covers four prefectures including the Tokyo central area. The total length is about 280 km and about 1.15 million vehicle trips are counted per day. Because of the frequent congestion, provision of travel time information through variable message signs, the MEX-i robot, and the highway telephone has been a quite demanded user service. All routes on Metropolitan Expressway are shown in Fig.1.

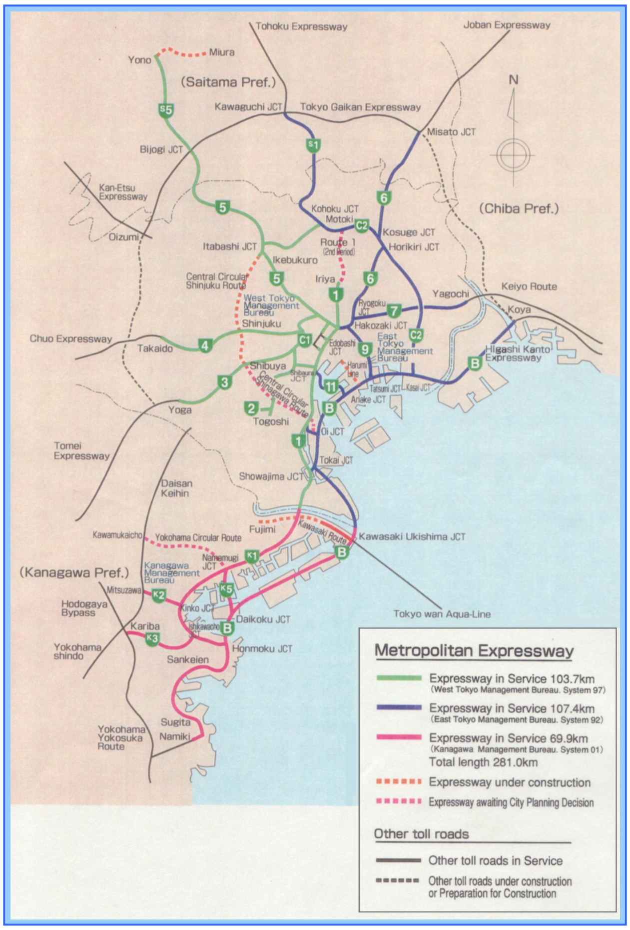

Fig.1: All routes on MEX

However, the difference between the information service travel time and the actual one is sometimes large during incident occurrence, because the information service travel time is made based on past and current traffic conditions at the information offer time[1][3].

Then, we need to develop a methodology of travel time prediction during incidences, which would be even more valuable and beneficial.

As a first step, we here analyze impacts of incidents on traffic flow using collected data of inbound traffic on Route 3 Shibuya line.

We plan to analyze the data, and to propose a travel time prediction method by the following six steps. In this paper, we discussed about step-1 and step-2 only.

<Step-1> data collection and adjustment

<Step-2> analysis of traffic data

<Step-3> analysis of accident data

<Step-4> comparison of result between step-2 and step-3 (prediction of time during accident)

<Step-5> proposal of travel time prediction method

<Step-6> verification

2. Study route

In this paper, we focus on inbound traffic on Route 3 (the length of about 12 km) which is shown in Fig.2 and in Table-1. Among 17 sections in the figure, we use section data except sections 1, 2, and 17, because sections 1 and 2 are at a part of junction, and section 17 is further upstream than the Toll Gate on the main line.

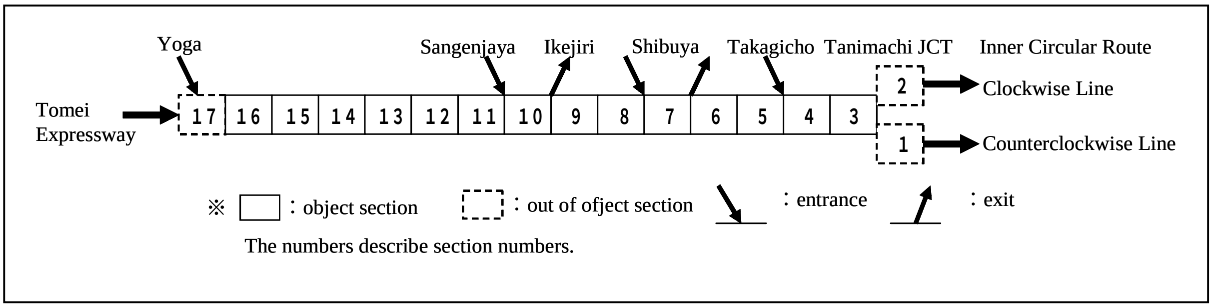

Fig.2：Study route（Route 3 on MEX）

Table-1：Data of the study route

Entrance / Exit	Distance	Section No.
Yoga entrance & Yoga toll gate on line	490 m	Section 17
	5170 m	Section 16,15,14,13,12,11
Sangenjaya entrance		
	200 m	Section 10
Ikejiri exit		
	1750 m	Section 9,8
Shibuya entrance		
	940 m	Section 7
Shibuya exit		
	1570 m	Section 6,5
Takagicho entrance		
	1610 m	Section 4,3
Tanimachi JCT		
	130m/210m	Section1 / Section2

3. Study data

In this study, we analyze the traffic data (section data) during incident occurrence and the accident record data.　This section surveys all the data sources.

3. 1 Incident data

The incidents on road can be classified various types such as accident, beak down, falling object, road work, etc.

Fig.3 shows relation between the actual incident and the data which are available.

The details of each data type shown in Fig.1 are as follow:

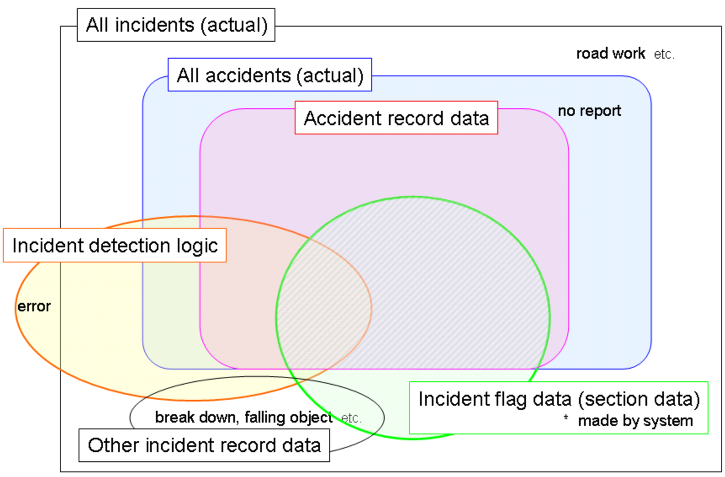

Fig.3：Relation of incident data

(a) All incidents (actual）

This data is all the incident data on the MEX such as accident, break down, falling object road work, etc.

It is practically difficult to capture all incidents, because some accidents or beak down are not reported.

(b) All accidents（actual）

This data is all the accident data on the MEX.

It is practically difficult to capture all accidents, because some accidents are not reported.

(c) Incident flag data (section data）

This data is manually registered into the data collection system by the road-traffic controller, based on the controller’s assessment that the incident impacts on traffic flow.

Section data includes incident flag data and the traffic data such as traffic volume, average velocity, and occupancy of the section.

This incident flag data means accident, break down, falling object, or road work has occurred but the type of incident is not specified.

(d) Accident record data（data recorded after the event）

This data contains all the accident data on MEX checked by Metropolitan Expressway Public Corporation (MEPC) such as MEX-Patrol-Car turned out.

The accidents recorded are found; for example, by MEX-Patrol-Car, by the traffic controller on CCTV, and so on. Since this data is recorded after the event, it is not an on-line data.

(e) Other incident record data (data recorded after the event)

This data contains all the incident data except accident and road work on MEX checked by MEPC like MEX-patrol car turned out.

The accidents recorded are found; for example, by MEX-Patrol-Car, by the traffic controller on CCTV, and so on. Since this data is recorded after the event, it is not an on-line data.

(f) Incident detection logic [4]

This logic detects the incidents using the traffic data from sensors.

The logic also detects the incidents which are not found in the accident record or incident flag. However some of these incidents may be false due to detection error.

The data which we can obtain and can be used for analysis is (c), (d), (e) and (f). However, it contains data which are recorded after the event.

3. 2 Study data

We use the section data and the accident record data on the study route.

For each of the section, traffic detector data is aggregated in every 5 minutes. This data is called section data which includes the incident flag data. Using two years (from 2001 to 2002) of section data, a database consisting of over 1,000 records was built.

A second database was built using one year (2001) accident record data which are logged by MEPC such as MEX-Patrol-Car turned out. This database consists of about 600 records. During last two years, roughly 30,000 traffic accidents occurred, and approximately 50 minutes was needed to clear up the accidents on all routes of MEX.

In this study, we focus on accidents only and in the analysis, we analyze section data for one month period (October, 2001) of section data, accident record data and other record data that have been collated. For this one month, incident flag data, accident record data, and other record data have 89, 42 and 132 records respectively. These data are records of actual incidents. Therefore, the total number of incident flag and the sum of accident and other incident record data must fundamentally be in agreement. However, since incident flag data means that the incident has some level of impact on traffic flow, and record manually by MEPC, it is not necessarily in agreement as illustrated Fig.3.

In the data used for this study, as Table 2 shows, the number of cases which is in agreement with incident flag data are 18 in accident record data, 50 in other incident record data, and 68 in total.

In this study, cases in agreement with incident flag data and accident record data are analyzed.

Table-2：Relation between incident flag data and accident record data

Data	total	match	rate
incident flag	89	68*1	76.4%
⇕	⇕	⇕	⇔
accident record	42	18*2	42.9%
other record	132	50*3	37.9%

※ total ： Total of each data for one month

※ match ：*1 ⇒ The number of cases which was in agreement with accident or other incident record in incident flag data

*2 ⇒ The number of cases which was in agreement with incident flag data in accident record data

*3 ⇒ The number of cases which wes in agreement with incident flag data in other incident record data

※ rate ： (match)/(total)*100 : each data

4. Analysis of section data during incident occurrence

4. 1 Way of analysis

1) Analysis by travel time curves

At first, we figure travel time curves of the day which incidents have occurred. The figures are plotted information service travel time (instantaneous travel time) and actual one, and accident data shown accident occurrence section and accident continuation time.

2) Analysis by cumulative curves

We have studied travel time prediction method using cumulative curves which describe the cumulative traffic counts over time along a route, although the method has not been examined during incident occurrence [2]. In this study, we paid attention to cumulative curves at first. And then, the change of pattern before and after the incident occurrence is analyzed.

Generally, the curves of each section don't cross if there is no entrance or exit on a route. However, in this case, the curves often cross on the study route because there are some entrances and exits on the way. The change of cumulative curves may indicate an incident occurrence. It is important to focus and to investigate them. The curves are adjusted by shifting each of them upwards so that the cumulative curves of each section don't cross on the way.

3) Analysis by time-space graphs

When we analyze incident impacts on traffic flow, there is a method of grasping a traffic condition in time and space. Although the cumulative curves are suitable for grasping change of the cumulative trips at a certain point, in order to grasp a time and spatial traffic condition, it needs to examine another technique.

Then, in order to grasp them, the time-space graphs of the traffic volume and average velocity were figured, and we analyzed them about change of the traffic condition before and after the accident occurrence.

4. 2 Result and consideration

1) Outline

As a result of analyzing their impacts on traffic flow based on the methods described in section **4.1**, it is able to classify into four types as clear cases. The cases are shown in the following.

(a) The accident has clearly impacted on traffic flow from the occurrence section to the upstream.

(b) The impacts have canceled on the way although it has impacted from the accident occurrence section to the upstream.

(c) It has impacted only at the only occurrence section.

(d) It has no impact.

Amongst the above 4 cases, the traffic condition during accident of (a) and (c) are easier to understand and are described below.

2) The case of clear impacts: (a)

About the case of clear impacts (a), travel time curves are shown in Fig.4, cumulative curves are shown in Fig.5, and each time-space graphs of traffic volume and average velocity are shown in Fig.6 and Fig.7, respectively. And then, the average change of cumulative curves at accident occurrence section before and after it is shown in Table 3.

Fig.5, 6, and 7 clearly show that traffic congestion has spread to the upstream with the passage of time under the impacts of accident, and it has been cleared to the upstream after processing the accident. As the result, a sharp increase and decrease of travel time from 14:30 to 17:00 is shown in Fig. 4. Table 3 shows that traffic capacity has decreased and passage traffic volume has become less than 1/2 for closing a lane because of accident occurrence.

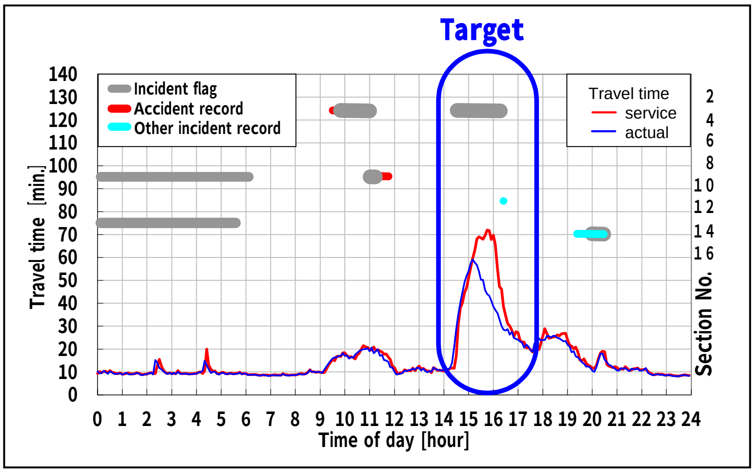

Fig.4: Travel time curves

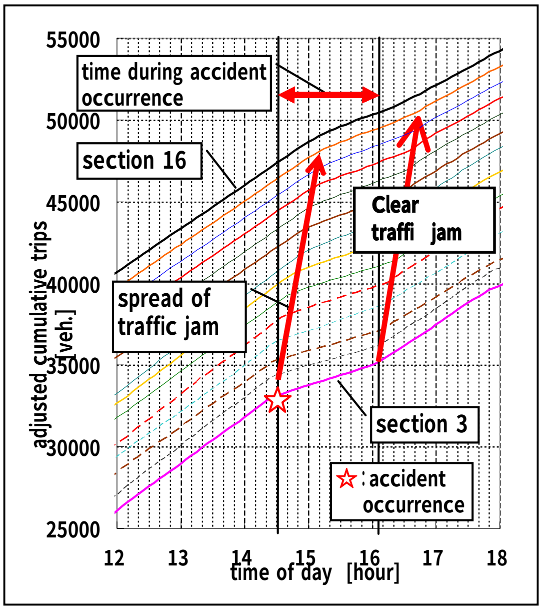

Fig.5: Cumulative curves

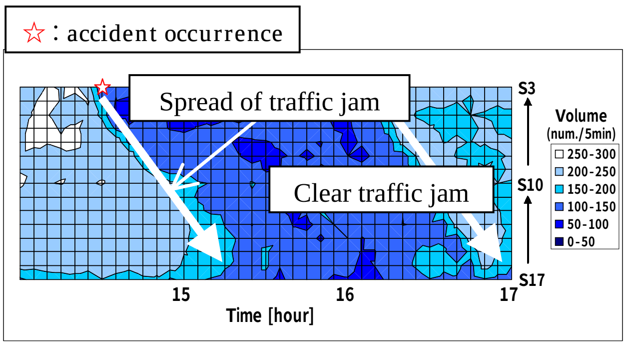

Fig.6: Time-Space graph <traffic volume>

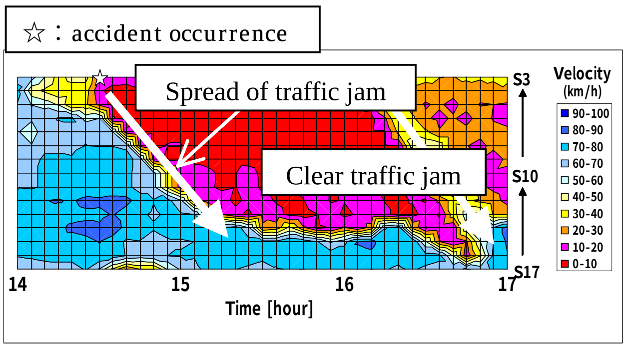

Fig.7: Time-Space graph <average velocity>

Table 3: Average change of cumulative trips before and after the accident

	1 hour before accident occurrence	During it	1 hour after accident clear
Average change of cumulative trips	233	111	215

* Average change of cumulative trips is traffic volume per 5 minutes.

2) The case of impacts only at the occurrence section: (c)

About the case of impacts only at the occurrence section (c), travel time curves is shown in Fig.8, cumulative curves is shown in Fig.9, and each time-space graphs of traffic volume and average velocity are shown in Fig.10 and Fig.11, respectively. And then, the average change of cumulative curves at accident occurrence section before and after it is shown in Table 4.

This is the case which the accident has occurred at section 13. Fig.10 and 11 show that although velocity has fallen at section 13 because of the accident, since it has been midnight, there has been little traffic, and the impacts have not spread to other sections. Although Table 4 shows that traffic volume has decreased at the section for closing a lane during accident occurrence, it hasn't practically impacted on cumulative trips at the other sections in Fig.9. And then, travel time has been impacted a little bit in Fig.8. Therefore this is a clear case of impacts only at the occurrence section.

On the other hand, comparing Table 3 with Table 4, both of traffic volumes during the accidents are about 100 counts per 5 minutes, respectively. However, traffic volume before and after the accident in Table 4 is 60% of the traffic volume in Table 3. It can be considered that these differences have become the different accident impacts on traffic flow.

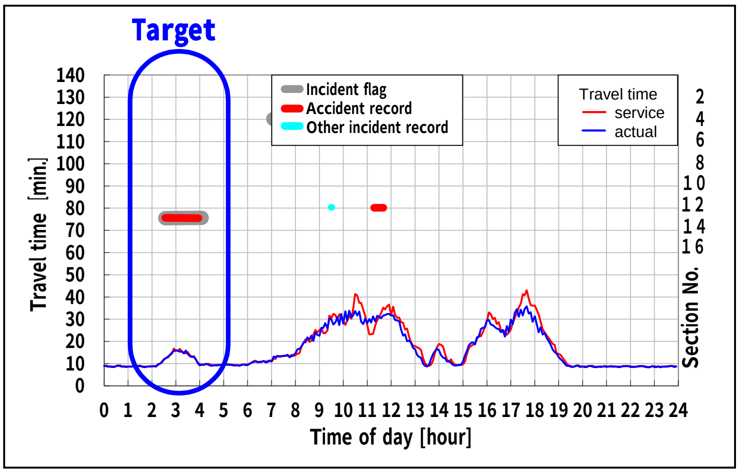

Fig.8: Travel time curves

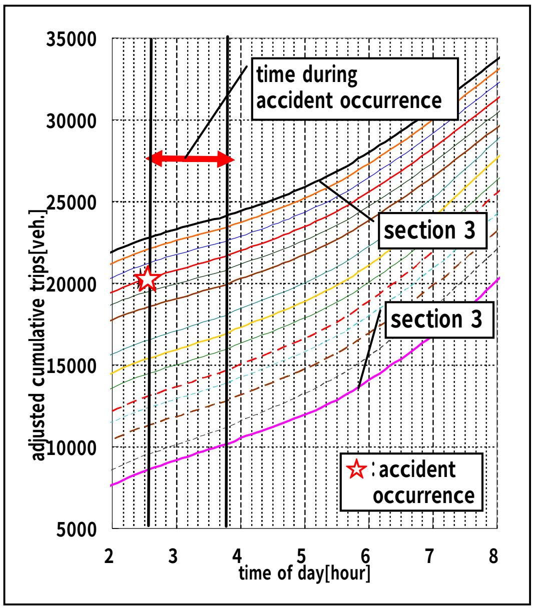

Fig.9: Cumulative curves

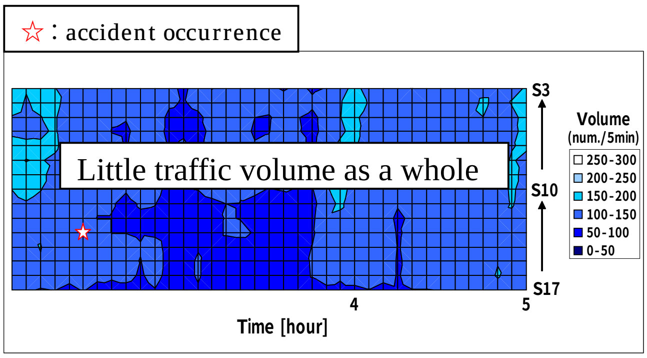

Fig.10: Time-Space graph <traffic volume>

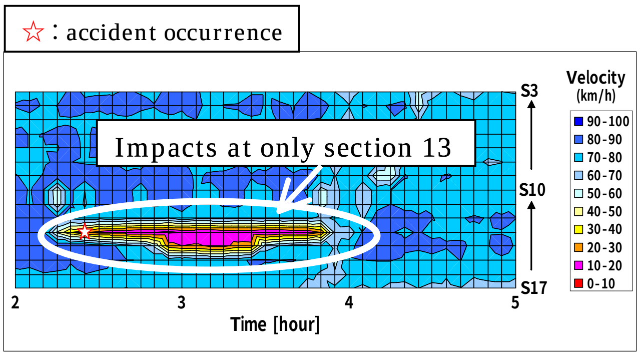

Fig.11: Time-Space graph <average velocity>

Table 4: Average change of cumulative trips before and after the accident

	1 hour before accident occurrence	During it	1 hour after accident clear
Average change of cumulative trips	149	99	123

* Average change of cumulative trips is traffic volume per 5 minutes.

5. Conclusion

We analyze the impacts of incident occurrences on traffic flow on the Metropolitan Expressway as the first step of travel time prediction study during incidents.

The followings are the major remarks:

- We showed the relation between the actual incident and the data which are available, and the details of each data type.
- For inbound traffic on Route 3 Shibuya line, the databases were built using two years traffic detector data and one year accident record.
- Based on this database, we analyze their impacts on traffic flow by drawing cumulative curves along the route and find that the cumulative curve is sometimes a good indicator of incident occurrence.
- As a result of analysis, it was able to classify into four types as clear cases.
  a) The accident has clearly impacted on traffic flow from the occurrence section to the upstream.
  b) The impacts have canceled on the way although it has impacted from the accident occurrence section to the upstream.
  c) It has impacted only at the only occurrence section.
  d) It has no impact.

Advancing analysis of section data, we will analyze and classify accident record data from now on. We plan to eventually propose a travel time prediction method during incident occurrence based on relation between accident form and traffic data.

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