ANALYSIS OF ROAD POTENTIAL AND BOTTLENECKS BASED ON PERCENTILE SPEED

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ABSTRACT
Vehicle detectors have been installed at approximately every 300 meters on each lane on Tokyo metropolitan expressway. Various traffic data such as traffic volume, average speed, and time occupancy are collected by vehicle detectors. We can understand traffic characteristics of every point by comparing traffic data collected at many points. In this study, we focused on average speed, analyzed road potential, and identified existing bottlenecks and latent bottlenecks. Furthermore, effects of congestion measures were examined by comparing percentile speed contours of each year. It's expected that this method of analysis will be utilized for installation of ITS such as drive assist, estimation of parameters of traffic simulators and feedback to road design as congestion measures.

1. INTRODUCTION

Vehicle detectors have been installed at approximately every 300 meters on each lane for the total length of 283.3km on Tokyo metropolitan expressway. Various traffic data such as traffic volume, average speed, time occupancy are collected by vehicle detectors and processed in order to provide traffic information about traffic congestion, constructions, accidents and traffic regulations and so on. Because traffic data are collected by very short space interval, we can understand traffic characteristics of every point by comparing traffic data collected at many points.
The algorism to identify existing bottlenecks systematically by average speed out of these traffic data has been developed (1). But this algorism identified only existing bottlenecks, and couldn't identify latent bottlenecks. In this study, we focused on average speed, and analyzed road potential. Here we assumed that road potential at the section where the drivers can stably drive at their target speed without speed reduction is high, and road potential at the section where the drivers cannot drive at their target speed with speed reduction by some factors is low. Concretely speaking, using traffic detector data of October in 2002, 2003 and 2004 on east Tokyo area of Tokyo metropolitan expressway, we identified existing bottlenecks and latent bottlenecks by calculating percentile speeds and percentile values of each point, figuring percentile speed contours connected by same percentile speed and percentile value contours connected by same percentile value in each route and each direction, and analyzing changes of these contours. In addition, comparing percentile speed at no rainfall time with that at rainfall time, we can understand the difference of road potential at the same point between at no rainfall time and at rainfall time. Furthermore, we can understand effects

of the two congestion measures conducted since 2002 by comparing percentile speed contours of each year.
It’s expected that we can use the results of this study as basic data for installation of ITS such as drive assist, estimation of parameters of traffic simulation and feedback to road design. This paper reports the result of analysis and refers to development in the future.

2. IDENTIFICATION OF BOTTLENECKS

2.1 Data for Analysis

In this study, we analyzed data shown in Table 1.

Table 1: Data for analysis

Item	Object
Route	All routes of east Tokyo area of Tokyo metropolitan expressway (See Figure 1)
Data	Vehicle detector data aggregated by 5 min
Period	From Oct. 1 to Oct. 31 in 2002, 2003 and 2004

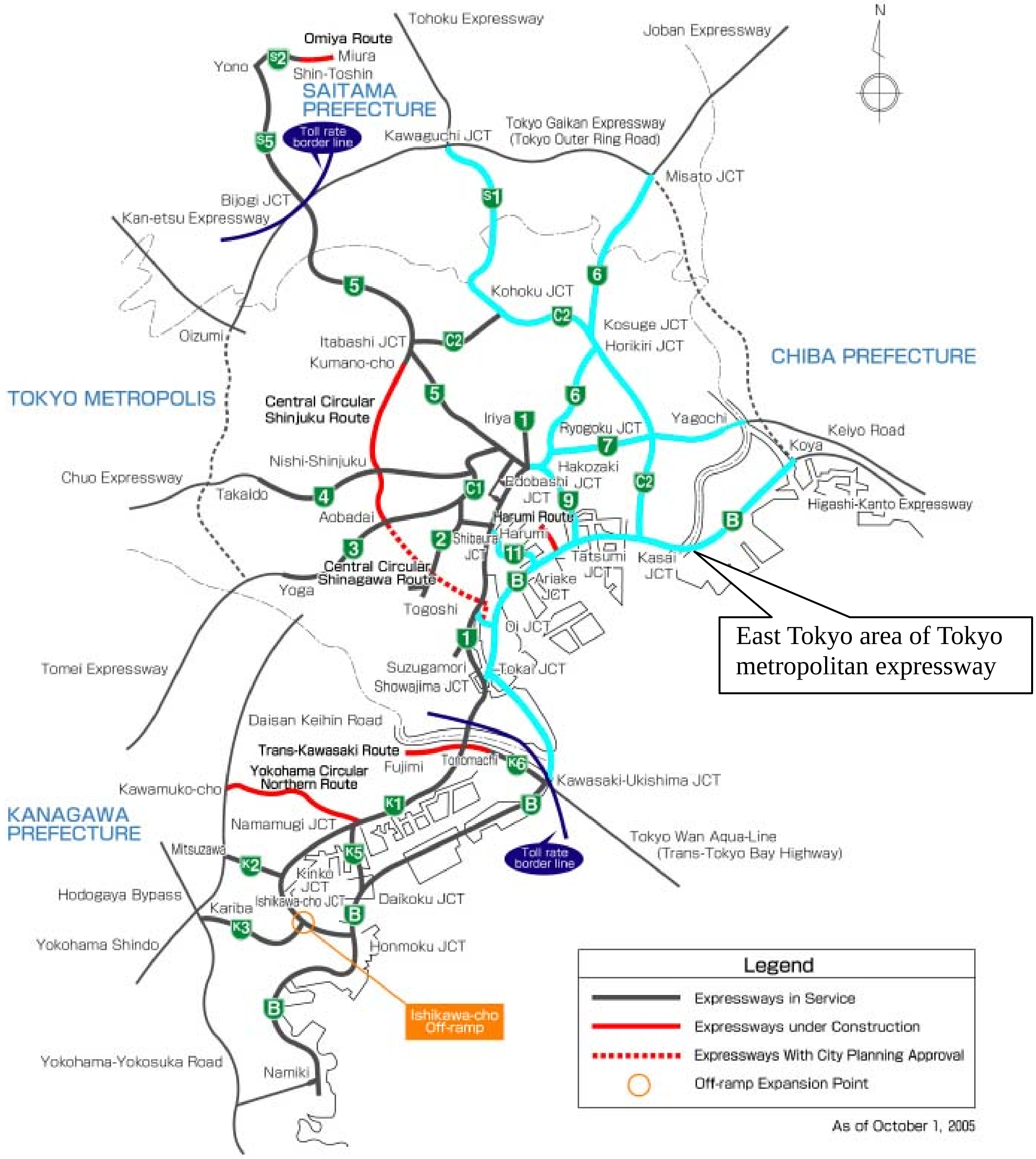


Figure 1: Network of Tokyo metropolitan expressway

2.2 Method of Identification of bottlenecks

2.2.1 Definition of percentile speed and percentile value

A percentile speed and a percentile value are defined below.

(i) Percentile speed

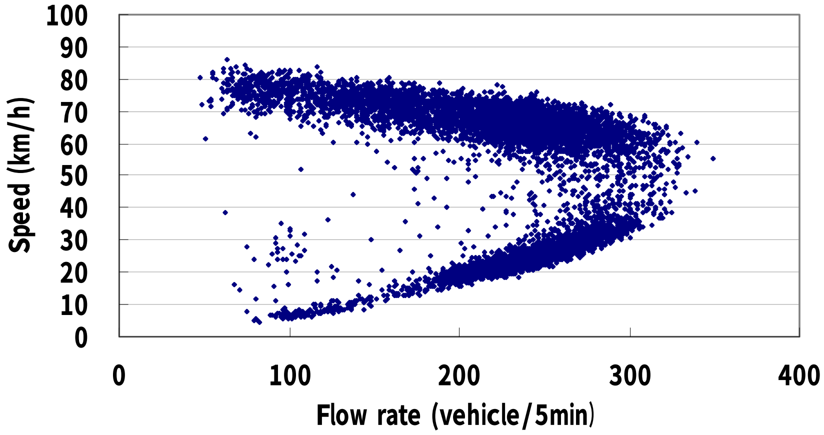
The speed-flow relationship for the cross section upstream of merging area at Hakozaki rotary on outbound Route No.6 (Mukojima) is shown in Figure 2. And frequency of appearance of data in Figure 2 is shown in Figure 3. In Figure 3, a percentile speed is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. For example, the number of data in October is 8,928 as calculated below.

*The number of data = 31 (days) * 24 (h) * 60 (min) / 5 (min) = 8,928*

The 90 percentile speed is the 893rd highest speed, which is equal to 73.4 km/h in Figure 2. In addition, a percentile speed is calculated except data which are backed up neighboring vehicle detector data to, or are deficient.

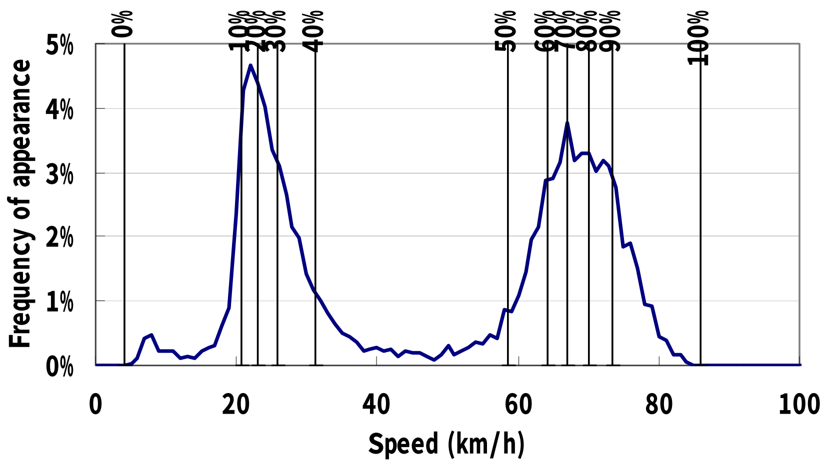
(ii) Percentile value

A percentile value is percentile for each speed. For example, 20 km/h is 6.5 percentile in Figure 2. 40 km/h is 44.5 percentile, 60 km/h is 51.4 percentile, and 80 km/h is 99.2 percentile as well.



* Period for aggregation: 2004/10/1 ~ 10/31

Figure 2: Speed-flow relationship



* Aggregating frequency of appearance of speed by 1km/h unit

Figure 3: Distribution of speed and percentile speeds in speed-flow relationship

2.2.2 Definition of bottlenecks

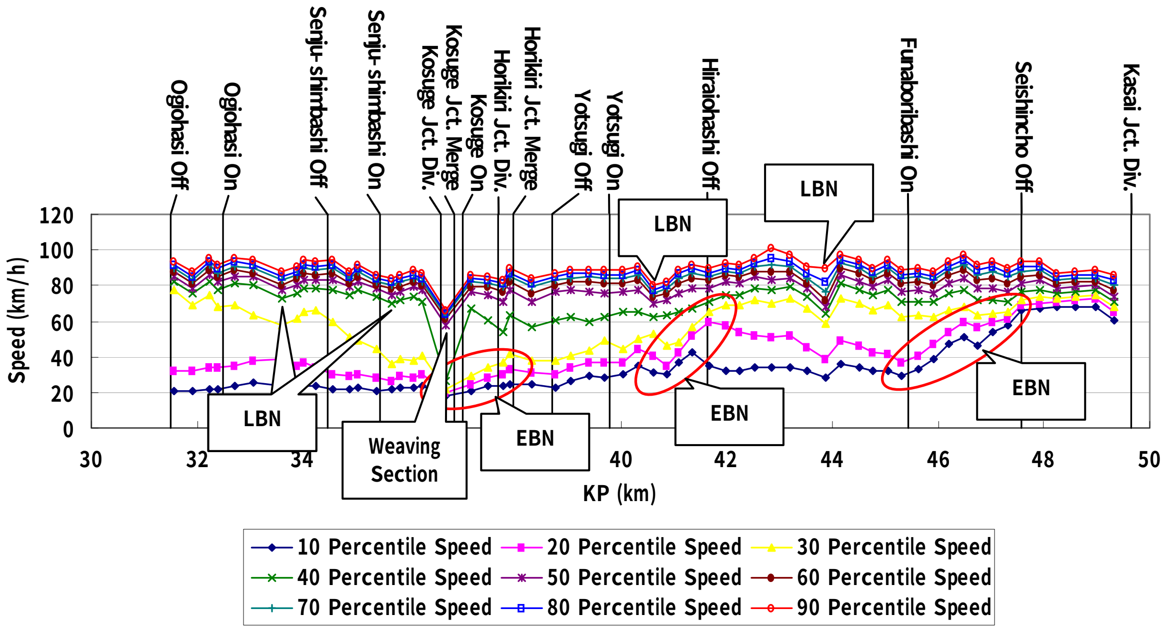
Existing bottlenecks and latent bottlenecks are identified, considering changes of percentile speeds and percentile values aggregated by each route and each direction.
We defined an existing bottleneck and a latent bottleneck below and identified them.

(i) Existing bottleneck
We define a point where a low percentile (approximately 0 ~ 50) speed becomes drastically lower than that of downstream points as an existing bottleneck, or a percentile value of speed less than the critical speed (for example 40 km/h) becomes higher than that of upstream points.
This means that speed reduction occurs at this point, and this point is located near a bottleneck. However, we can't specify the precise location of a bottleneck because it's difficult to distinguish between a bottleneck where speed reduces and a downstream section of a bottleneck where speed slightly recovers.

(ii) Latent bottleneck
We define a point where a high percentile (approximately 80 ~ 90) speed becomes drastically lower than that of upstream points as a latent bottleneck, or a percentile value of speed more than the critical speed (for example 80 km/h) becomes higher than that of upstream points.
Road potential of these points is low because the condition of horizontal alignment, longitudinal gradient or road structure isn't good. If speed reduction occurs in the condition that traffic density is high, space between two vehicles becomes closer and traffic flow becomes unstable. If traffic demand increases, these points may become bottlenecks in the future.

2.3 Result of Identification of bottlenecks

The results of identification of existing bottlenecks and latent bottlenecks on Central circular route outbound (Kohoku junction (afterward, Jct.) ~ Kasai Jct.) are shown in Figure 4 and Figure 5. Horizontal alignment (see Figure 6) and longitudinal gradient (see Figure 7) in addition to percentile speed contours and percentile value contours are shown in order to understand the reasons of changes in contours.
Every point identified as an existing bottleneck is an observed typical bottleneck such as the sags near Funaboribashi on ramp and Hiraiohashi off ramp, and the weaving section between Horikiri Jct. and Kosuge Jct.. Consequently, this method of identification of bottlenecks is considered as appropriate.
Every point identified as a latent bottleneck is considered as appropriate in view of horizontal alignment, longitudinal gradient and landmarks. For example, a factor of speed reduction near 41 KP (Kilo Post) is horizontal alignment, also 34 KP and 36 KP, longitudinal gradient. And a factor of speed reduction near 44 KP may be peculiar landmark.
In the same way, existing bottlenecks and latent bottlenecks on east Tokyo area of Tokyo metropolitan expressway are identified, and this method of identification of bottlenecks is considered as appropriate.



* LBN = Latent Bottleneck, EBN = Existing Bottleneck

Figure 4: Percentile speed contours

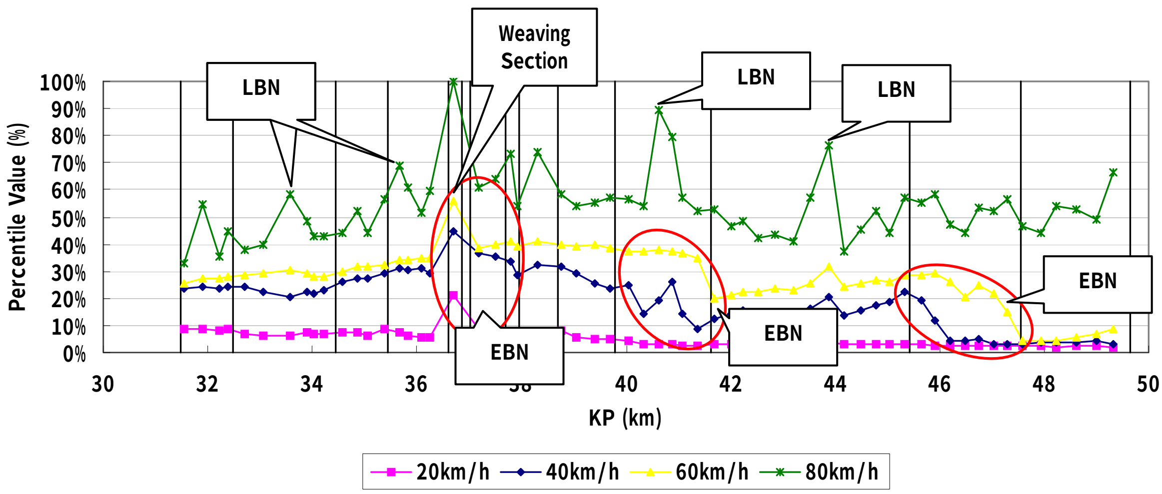
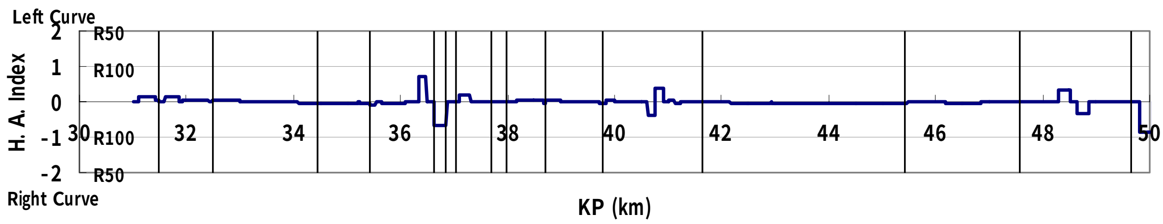


Figure 5: Percentile value contours



* Horizontal Alignment Index = 100/curvature radius

Figure 6: Horizontal alignment

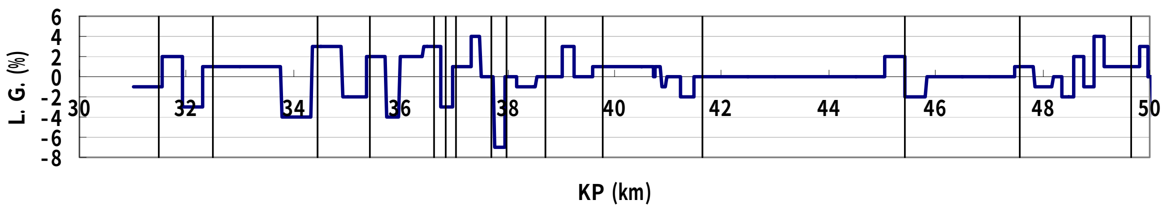


Figure 7: Longitudinal gradient

3. CHANGE OF ROAD POTENTIAL BY RAINFALL

Traffic capacity at rainfall time in the bottleneck near Hakozaki is lower than that at no rainfall time by 11% and average speed by 6% (1). And the higher rainfall is, the lower operating speed is (2) (3). This shows that road potential at rainfall time is lower than that at no rainfall time, and this study examined the influence of rainfall to road potential.
Percentile speed contours shown in Figure 3 are separated to percentile speed contours at rainfall time and no rainfall time (see Figure 8). Percentile speed contours at rainfall time and no rainfall time have almost same figuration and the difference of percentile speed is approximately 10 km/h. This shows that the relation of road potential level doesn't change by rainfall, but road potential becomes lower by rainfall.

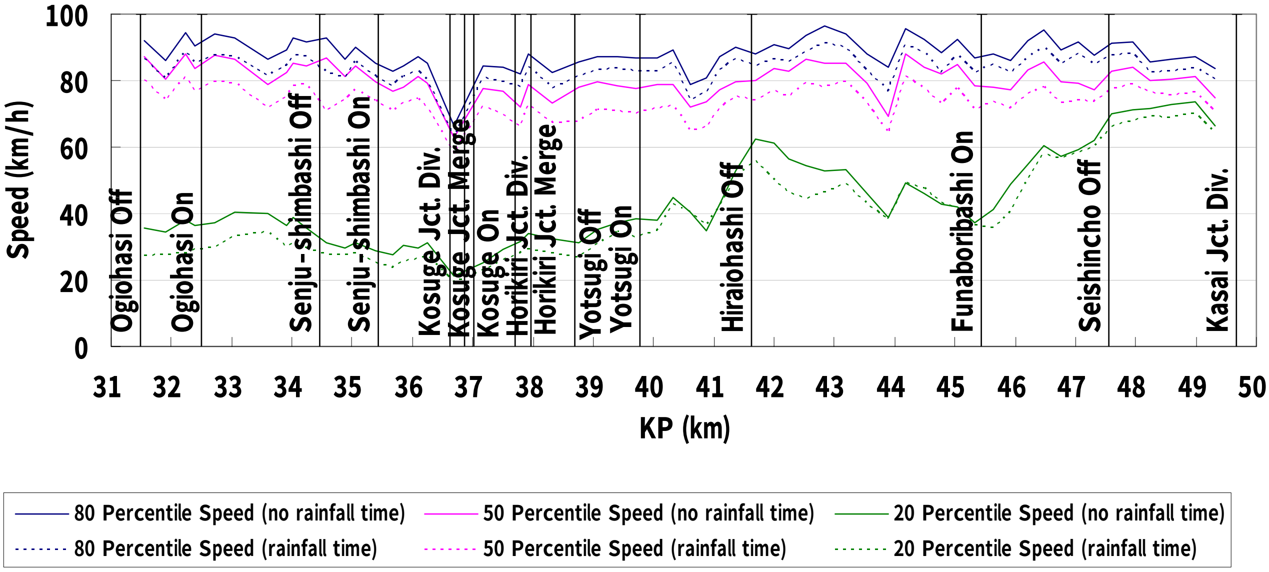


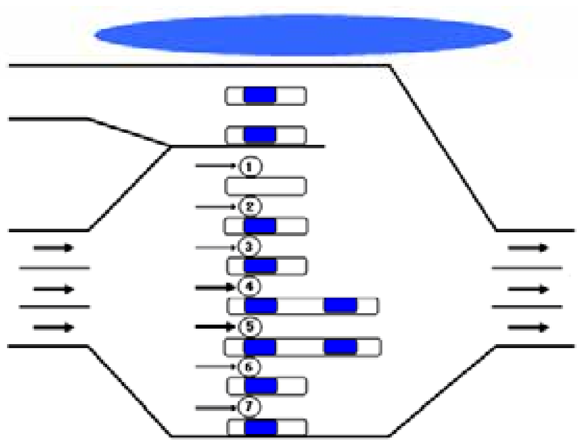
Figure 8: Comparison of percentile speed at rainfall time and no rainfall time

4. EXAMINATION OF EFFECTS ON CONGESTION MEASURES

We analyzed effects of congestion measures with the use of percentile speeds.

4.1 Penetration of ETC and Installation of Double Booth in Oi Toll

Installation of double booth in Oi toll on eastbound Bay shore route for the purpose of reduction of congestion is shown in Figure 9. The 4th and 5th lanes have been operated as double booth since A.M.6:00 on May 29, 2003. In addition, ETC has steadily been penetrated (the average ETC utilization rate of Tokyo metropolitan expressway: Oct. 2002 is approximately 4 %, Oct. 2003 is approximately 13 % and Oct. 2004 is approximately 26 %). It is considered that increase of throughput capacity in during busy hours by these synergic effects has effect on easing congestion in toll.
The secular change of percentile speed of lane 3 on eastbound Bay shore route is shown in Figure 10. The percentile speed of points upstream of Oi toll in 2003 and 2004 is higher than that in 2002 before installation of double booth. And yet at the same time, the percentile speed of points downstream of Oi toll in 2003 and 2004 is lower than that in 2002 before installation of double booth.
This shows that traffic congestion has been eased because traffic capacity of Oi toll has increased by penetration of ETC and installation of double booth and at the same time a latent bottleneck between Ariake on ramp and Ariake Jct. (merge) has changed to existing bottleneck as the result of bottleneck's transition to downstream.



*Double booth: two tandem toll booth in order to collect toll from two vehicles at the same time, resulting in improvement of traffic capacity

Figure 9: Installation of double booth in Oi toll

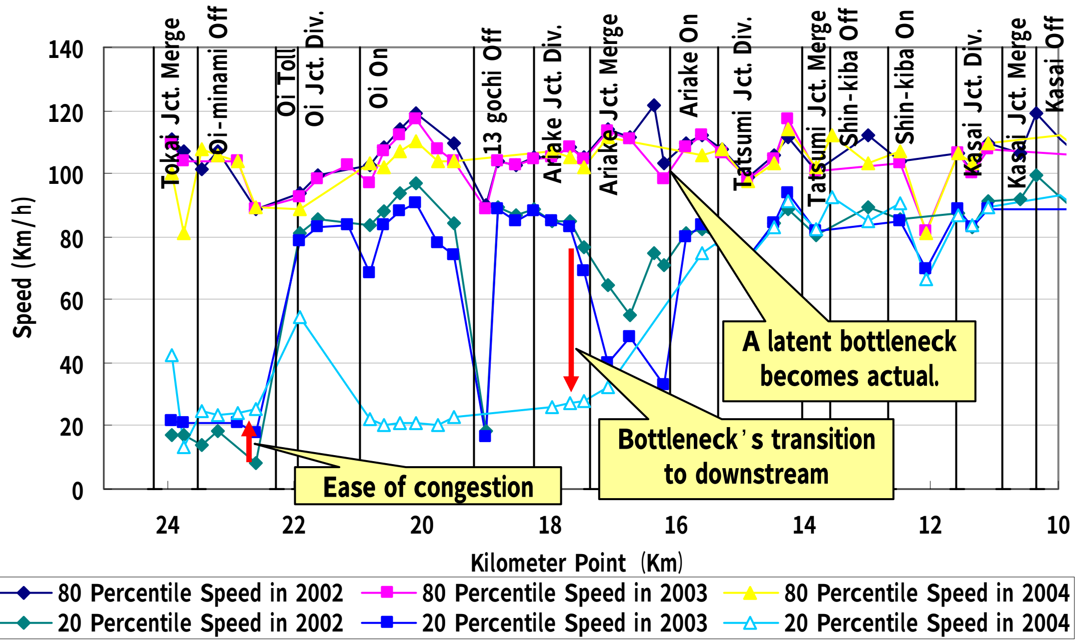


Figure 10: Percentile speed of lane 3 on eastbound Bay shore route

4.2 Improvement of the Section between Shin-kiba Jct. and Tatsumi Jct.

The section around Shin-kiba on/off ramps on the westbound Bay shore route is one of the most heavily loaded sections because of the confluence of the traffic from the Bay shore route and that from the Central circular route outbound at Kasai Jct.. Traffic congestion usually occurs during morning and evening busy hours.

The improvement work on the section between Shin-kiba and Tatsumi Jct. was to increase the number of additional lanes in each direction in order to ensure a smooth flow of traffic that ramifies and traffic that converges in that section. The work was completed and opened on September 17, 2004 (4).

The secular change of percentile speed of lane 3 on westbound Bay shore route is shown in Figure 12. This figure shows that congestion had occurred at the section around Shin-kiba on/off ramps before improvement (in 2002 and 2003), but congestion have not occurred after improvement (in 2004).

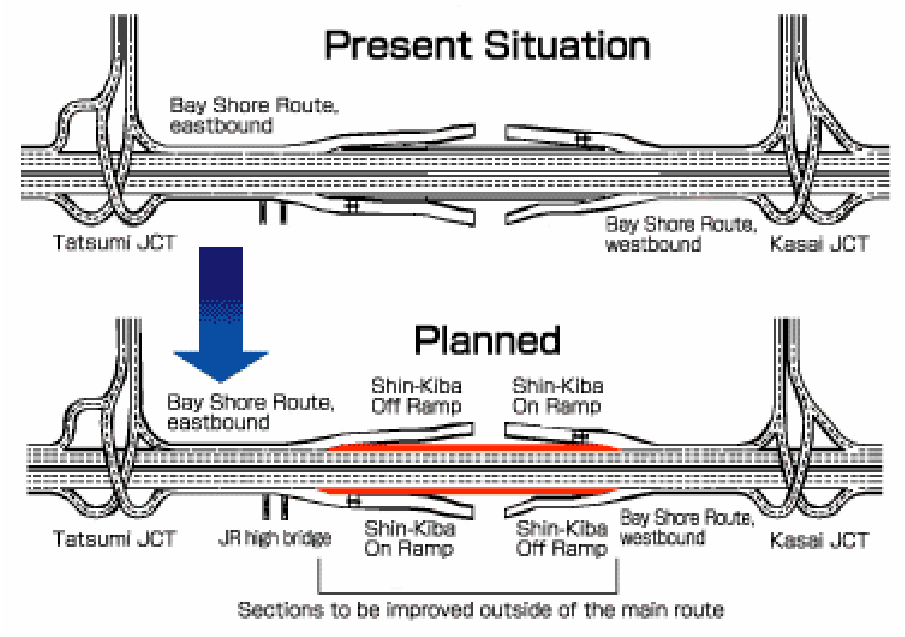


Figure 11: Improvement of the section between Shin-kiba Jct. and Tatsumi Jct.

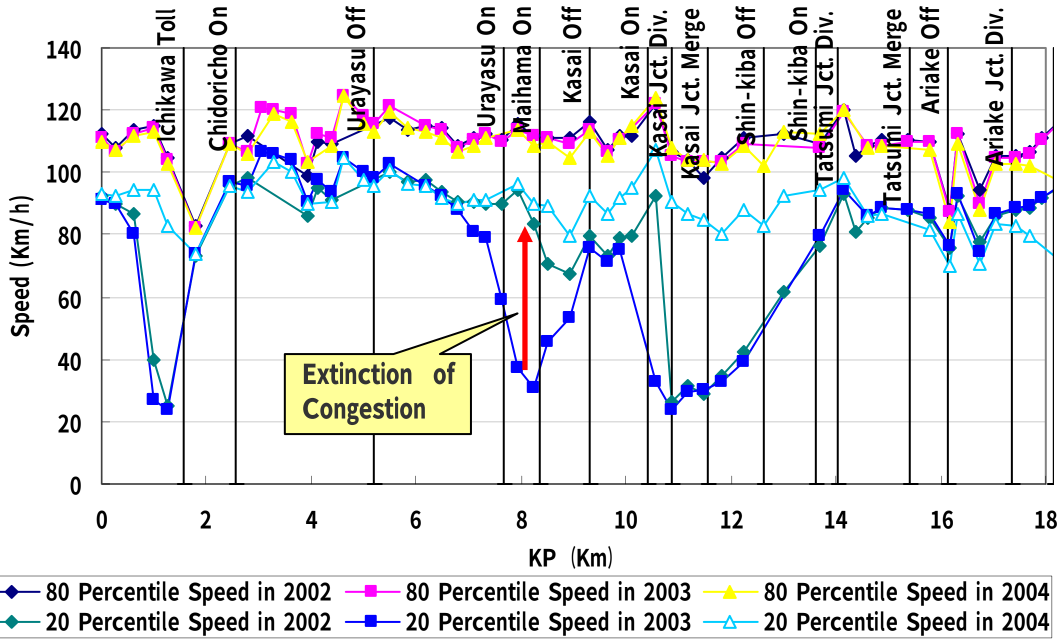


Figure 12: Percentile speed of lane 3 on westbound Bay shore route

5. CONCLUSION AND FUTURE TASKS

In this study, percentile speeds and percentile values were calculated by vehicle detector data aggregated by 5 min. But these aggregated data calculated with the use of data of all the vehicles that included vehicles following the forward vehicle. Consequently the result of calculation doesn't completely reflect the operating speeds. If only data of free flow vehicles identified from pulse data are aggregated, it is obvious that more precise road potential can be calculated. In another view, it's expected to calculate and compare speed distribution under the same conditions such as same traffic volume.

Judging from changes of percentile speed contours and percentile value contours, we qualitatively determined both existing bottlenecks and latent bottlenecks in this study. We must make the threshold for determination clear, and quantitatively determine both existing bottlenecks and latent bottlenecks.

Besides, it's necessary to validate the application to other latent bottlenecks with the similar condition such as horizontal alignment, longitudinal gradient and road structure. If possible, we may be able to calculate traffic capacity of latent bottlenecks and points on new routes.

In later stage, installation of ITS below will be expected as congestion measures with the use of road potential analysis.

(i) Contribution for reducing congestion because of road potential improvement of low potential points by drive assists with the use of ITS technology such as ACC, AHS and so on

(ii) Estimation of parameters of traffic simulation for assessment of measures against congestion

(iii) Road design not to reduce road potential because of feed back to road design.

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