A STUDY ON THE ANALYSIS OF THE ROAD TRAFFIC SERVICE CHARACTERISTIC CORRESPONDING TO SNOWFALL AND ON THE ESTIMATION METHOD OF BENEFITS BY SNOW REMOVAL BASED ON THE ANALYSIS

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ABSTRACT

In this research, the influence on the road traffic by the snow coverage in winter is analyzed based on the positive data with which constant observation traffic data and traffic probe data were united properly, and the estimating method of benefits by snow removal on the running time shortening which is bringing road users more effects is proposed.
At first, the characteristics of the road traffic service in winter is analyzed by road conditions of roadside and number of lanes and by road surface conditions with constant observation traffic data and the weather survey data such as snowfall accumulation and the depth, etc, and the QVK performance curves, which indicate the relation between traffic volume (Q), spot speed (V) and traffic density (K), are presumed at each traffic data observation point. Next, the relation between the traffic data at the constant observation point and the traffic data of the probe at the link including the point concerned is analyzed on each link. Finally, the total travel time among some snow conditions at each link of road network is calculated, benefit by decreasing the total travel time by snow removal will be estimated by using this.

1. INTRODUCTION

1.1. Background

Approximately 60% of the land of Japan is located in snowy cold regions. About 20% of the population live in these snowy cold regions.
In snowy cold regions, snow removal ensures road traffic to maintain local economies and daily lives.
But, falling tax income of the national government and local governments and harsh opinions of investment in public works including maintenance within Japan has now forced the reduction of investment in public works. And the weakening of the construction industry as a result of a decline in public works investment and aging of society in snowy cold regions have resulted in insufficient support for snow removal. At the same time, residents need for snow removal is changing.
It is, therefore, essential to improve methods of managing roads in the winter.

1.2. Purpose

In order to improve winter road management, efficient snow removal and effective road selection methods should be derived.
To do so, the snow removal benefits for road traffic should be estimated and its effects compared. This paper is intended to clarify the relationship between the state of snow accumulation and road services in the winter and to present basic knowledge to estimate benefits based on changes in the level of road services.

1.3. Description and Positioning of this Research

This paper will clarify change of road traffic during the winter season for a specified region based on measured traffic data. And it calculates benefits based on time lost by changing speed.

2. METHOD

2.1. Research Flow

First, the QVK characteristics at observation locations are analyzed based on fixed point constant data. QVK characteristics are estimated by accumulated snow depth using meteorological data.
Next, the relationship of data representing speed at observation points with average over-all travel speed at links including the observation points is analysed considering accumulated snow depth for each link characteristic by road structure.
Based on these results, QVK characteristics are applied to each link of the road network in snow accumulation regions according to link characteristics, and the benefits are trial calculated based on traffic volume and average over-all travel speed.

2.2. Data Used

Research is done using fixed point observation data, probe data, and meteorological data.

2.2.1. Fixed point observation data

The analysis is done using fixed point constant traffic volume and point speed data.
In Japan, automatic observation equipment is installed at major points on arterial roads. The observation equipment constantly measures and records hourly traffic volume by type of vehicle (large, small) on inbound and outbound lanes. Some of the observation equipment also constantly measures and records hourly average point speed.

2.2.2. Probe Data

The analysis used over-all travel speed data for each road section based on probe data. The probe data which is used is obtained from cars equipped with car navigation systems that specified an auto maker has installed on its vehicles. Over-all travel speed data is organized by road sections which have been decided in advance.

2.2.3. Meteorological Data

The analysis is done using data measured by meteorological observation equipment installed at points adjacent to roads.
The meteorological data that is observed includes hourly snow accumulation, snow accumulation depth, air temperature, and road surface conditions. This research used hourly snow accumulation. The meteorological observation equipment is installed at locations which are not impacted by snow removal or snowdrifts.

2.3. Region and Period Studied

Japan is divided into 47 prefectures. and 60% of the area are in snowy cold regions. In this research 3 of these prefectures are focused on, and it is defined the period of snow accumulating is in January and February and the period of not accumulating is from September to October.

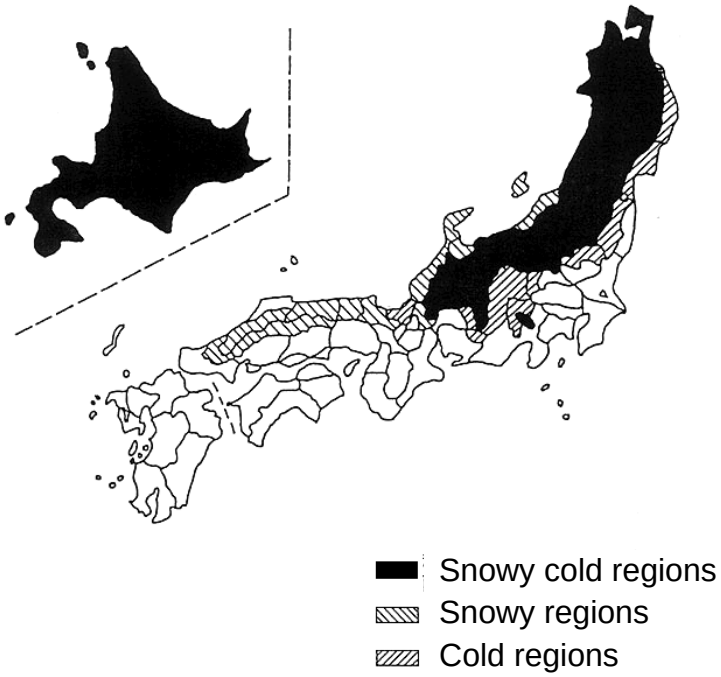

Figure 1 - Snowy Cold Regions of Japan and Areas Studied by this Research (MLIT HP)

3. ANALYSIS OF QVK CHARACTERISTICS BASED ON FIXED POINT OBSERVATION DATA

3.1. Method

Fixed point constant observation data are used to estimate QVK characteristics by hourly snow accumulation rank and by road conditions. The estimations derived Vf (free flow speed) and K0 (critical density) based on the Drake Equation. And Q0 and V0 were derived based on the following equations.

$$Q0=K0*V0$$

$$V0=Vf*\exp(-1/2)$$

For the hourly snow accumulation, the ranks in the table are set. The meteorological observation points and the traffic observation points do not conform, so the nearest meteorological observation points are linked to traffic observation points.

Table 1 - Hourly Snow Accumulation Rank

Rank	Hourly Snow Accumulation	Months
Autumn	None	September - October
Rank 1	0cm	January - February
Rank 2	Over 0cm - under 2cm	
Rank 3	Over 2cm - under 5cm	
Rank 4	Over 5cm - under 10cm	
Rank 5	Over 10cm	

Road conditions (link characteristics) are combinations of roadside condition and number of traffic lanes.

Table 2 - Categories of Road Conditions

Category	Items
Roadside condition	Mountains, flat land (excluding urban districts), urban districts
Number of traffic lanes	2-lane, 4-lane

3.2. Results

Based on fixed point observation data, QVK characteristics by hourly snow accumulation at each point are estimated and Q0, V0, and K0 are derived. Figure 2 shows the data, Q,V,K observed and line of QVK relational equation , and Figure 3 shows the results of calculating and plotting the average values of all data by hourly snow accumulation rank by road condition. It is hypothesized that on a 4-lane road in the mountains, there are few samples and appropriate results are not obtained. Although it varies by location, median values suggest that for every road condition, the more the hourly snow accumulation, the lower the value of Vf. K0, on the other hand, shows almost no change according to hourly snow accumulation.

Regarding differences according to road conditions, for Vf, by road condition of 2-lane roads, the average point speed increased in the order—mountains, flat land, urban districts—at almost every hourly snow accumulation rank. And differences according to hourly snow accumulation are by roadside condition, widest in the mountains, and by traffic lanes, widest on 4-lane roads.

For these reasons, the impact of hourly snow accumulation is higher in relation to the speed, and lower in relation to the traffic density.

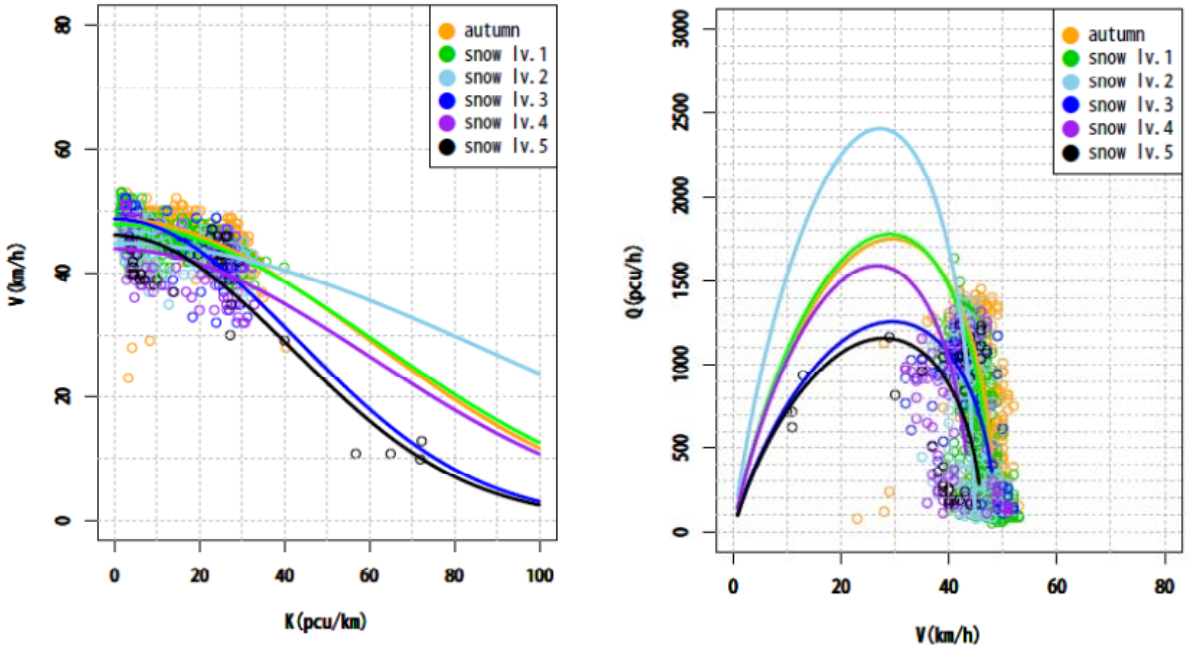

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Figure 2 - Example of Results of Estimating QVK Characteristics

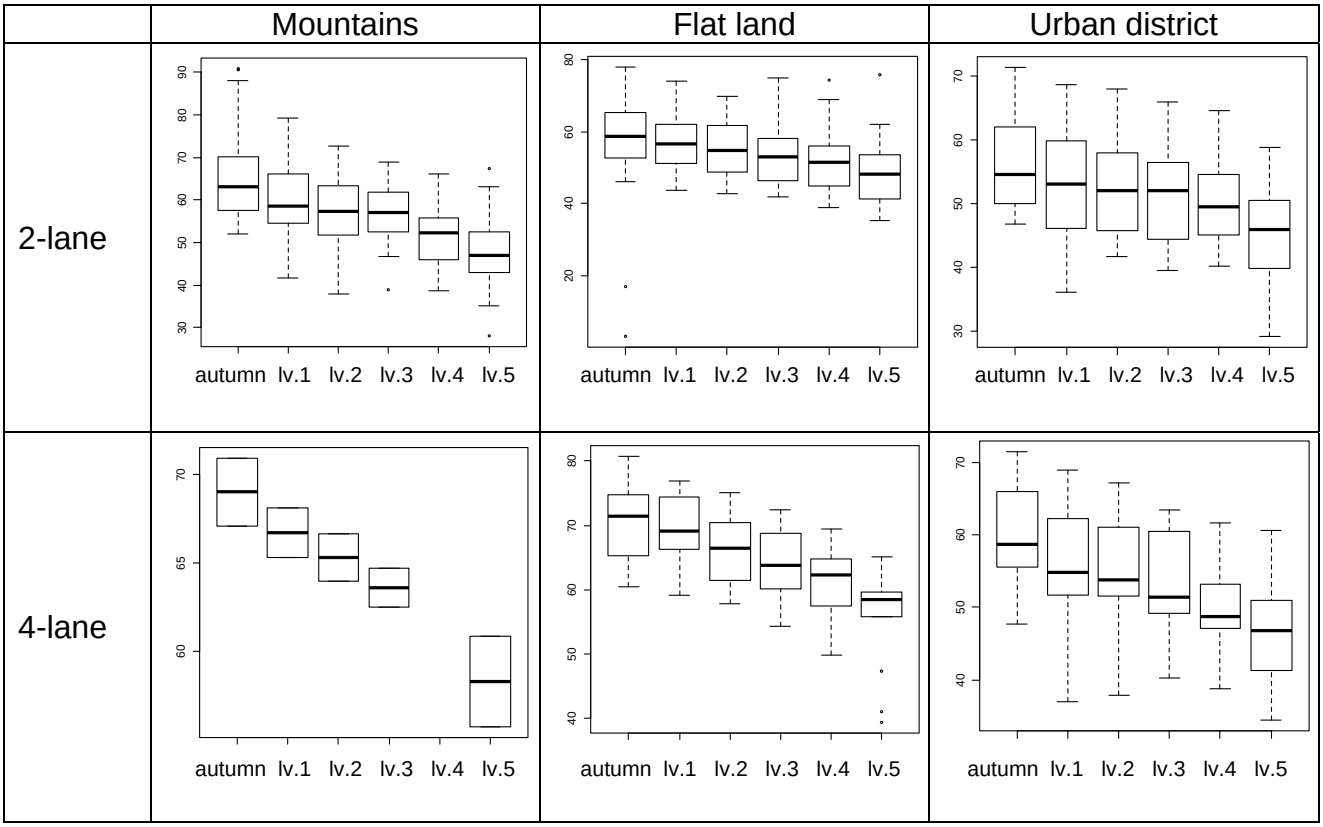

Figure 3 - Results of Estimating QVK Characteristics by Road Condition (Vf)

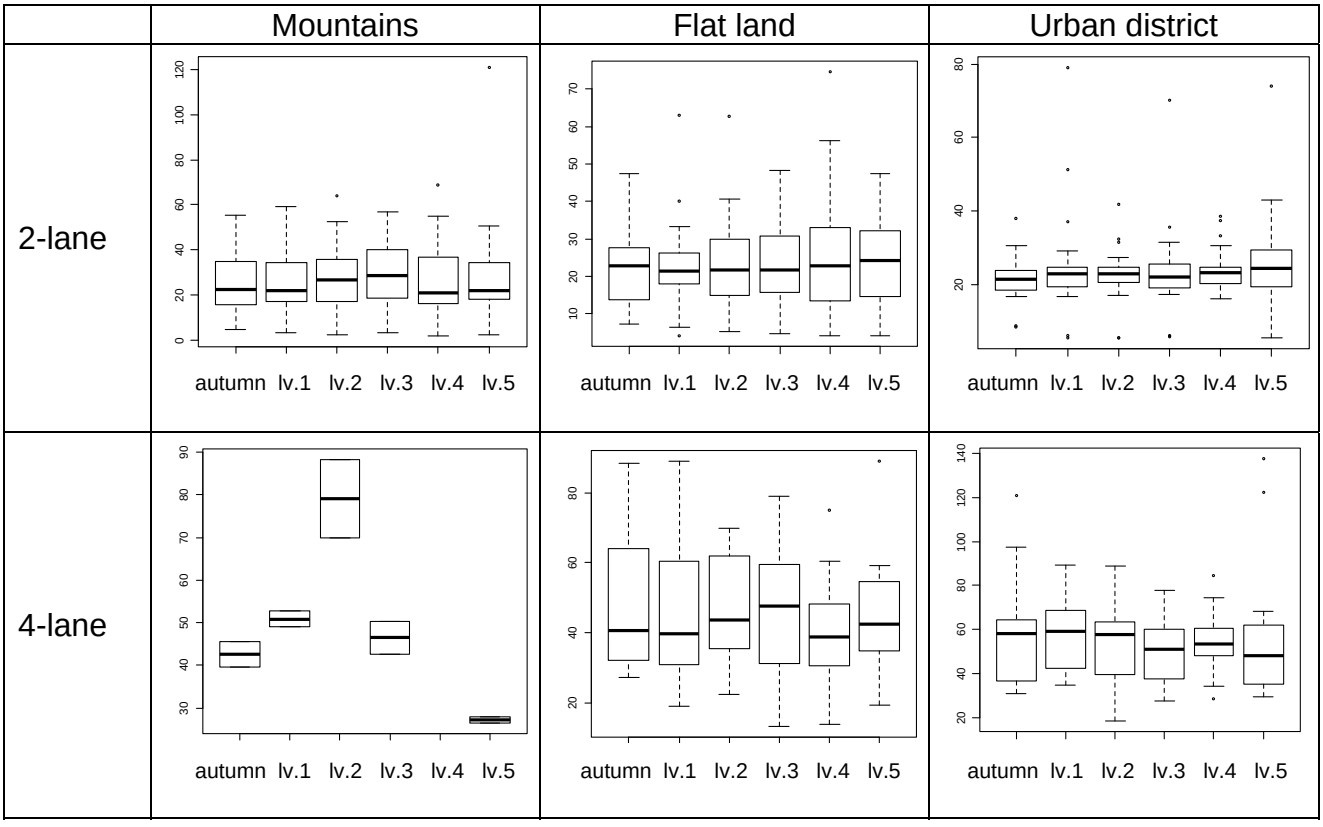

Figure 4 - Results of Estimating QVK Characteristics by Road Condition (K0)

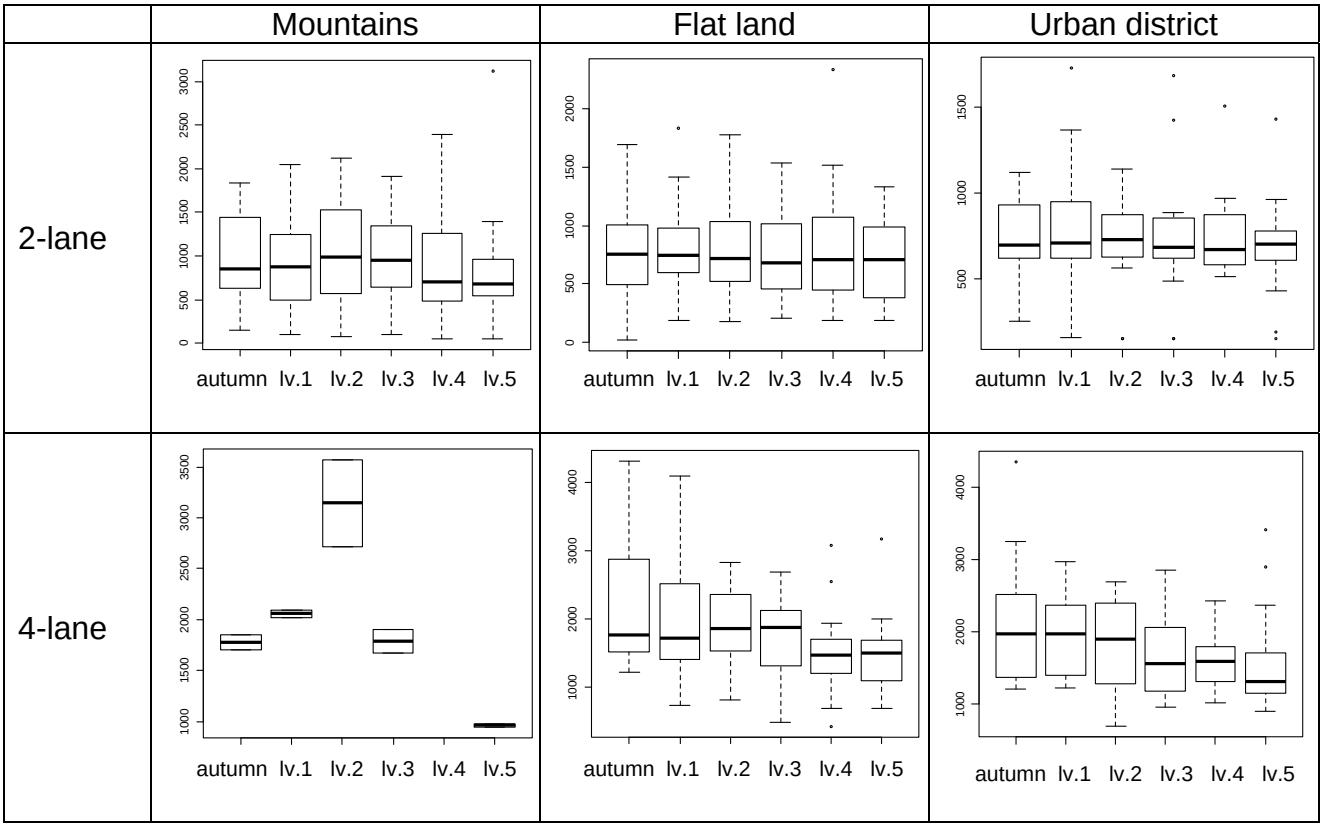

Figure 5 - Results of Estimating QVK Characteristics by Road Condition (Q0)

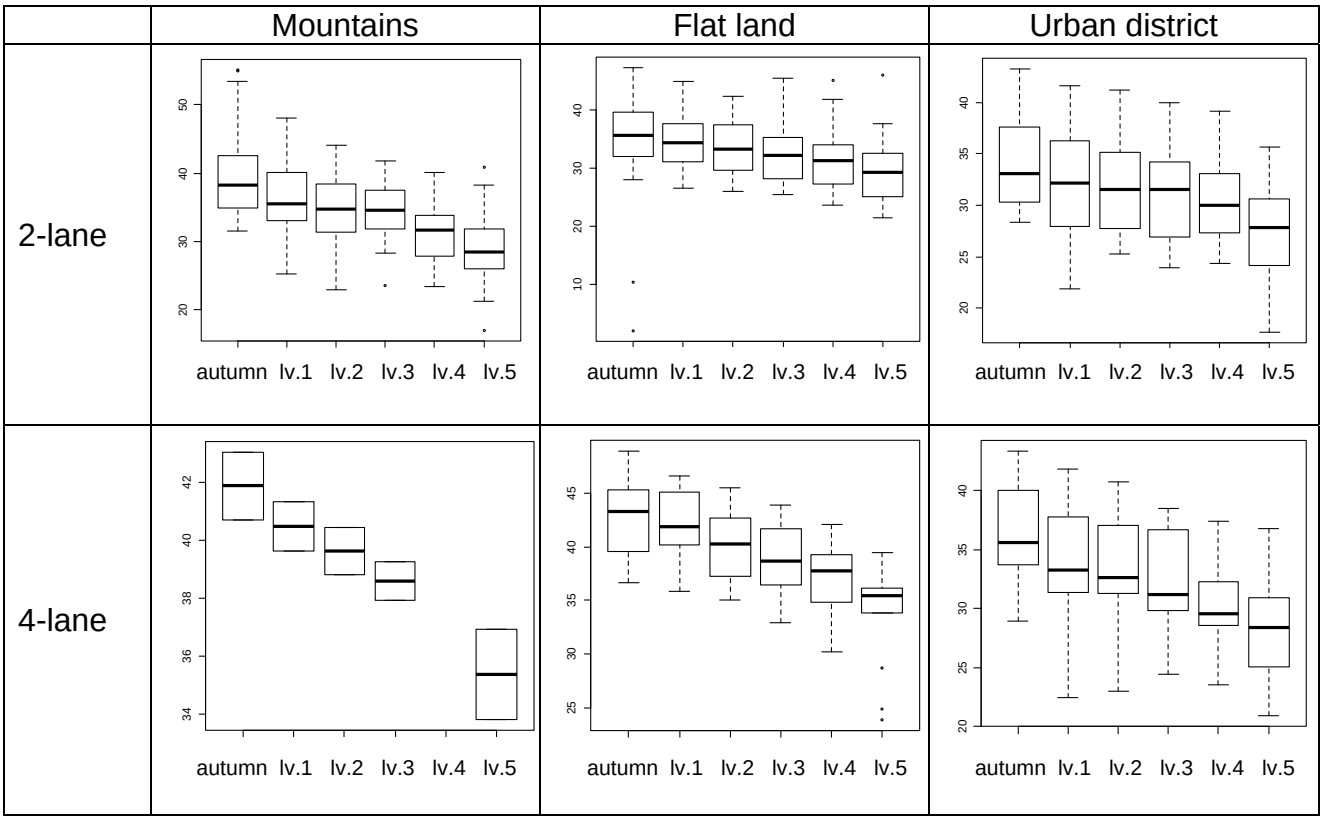

Figure 6 - Results of Estimating QVK Characteristics by Road Condition (V0)

4. ANALYSIS OF THE RELATIONSHIP OF SPEED FROM FIX POINT OBSERVATION DATA AND PROBE DATA

4.1. Method

In each section of a road network, over-all travel speed based on probe data is constantly obtained. In order to calculate the average point speed using QVK characteristics, the relationship of the average over-all travel speed and average point speed in each section is analysed. Based on this, both speed relational equation in each section is set.
But, average point speed is only observed in some sections, so in the future, it should be observed at appropriate times to set a travel speed - point speed relational equation in each section. In this report, it is presented using point speed data for some continuous observation points.

4.2. Results

The relationship of average over-all travel speed (probe V) and average point speed speed (traffic counter V) at optional locations is shown in Figure-7, -8. There are points where the travel speed is higher than the point speed and points where it is lower than the point speed. It is assumed that this is related to the locations where continuous observation equipment is installed for example.

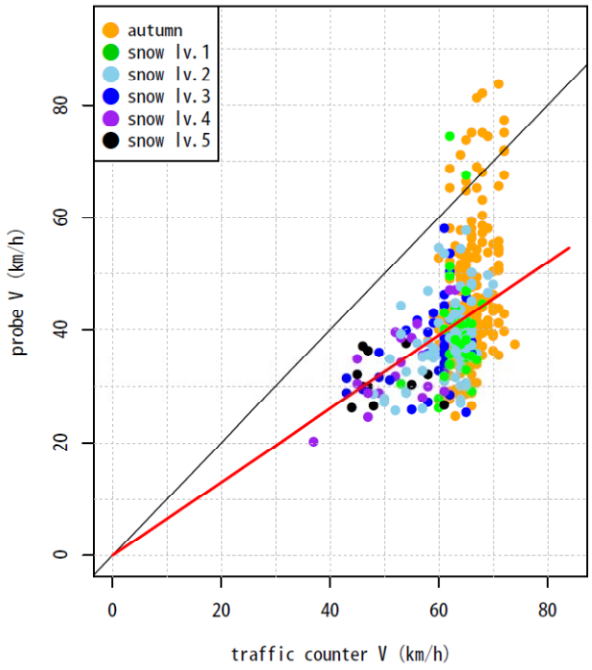

Figure 7 - Average Over-all Travel Speed - Average Point Speed (Example 1)

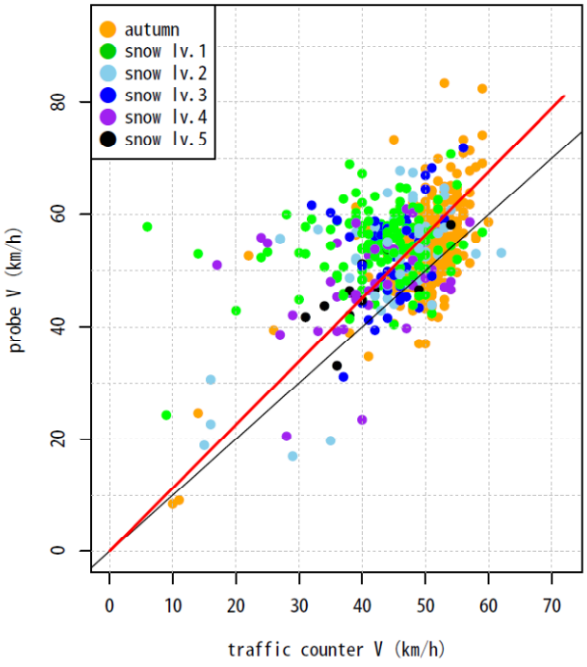

Figure 8 - Average Over-all Travel Speed - Average Point (Example 2)

5. BENEFIT CALCULATION

5.1. Calculating Total Driving Time

A calculation method applying the results of 3 and 4 is considered.

First, the values of QVK calculated in 3 are selected in one-hour units according to road conditions and hourly snow accumulation rank in the section.
Next, based on the average over-all travel speed estimated for each section, the relational equation in 4 is used to calculate the average point speed. In addition, the average point speed is applied to the QV equation to estimate the traffic volume. So here, it is hypothesized that the traffic situation is in a no-congestion range.
Based on this, the total travel time is obtained by the following equation.
By totalling the total travel time in each section that constitutes the road network, it is possible to clarify the total travel time of the road network.

$$\text{Total travel time} = \sum \left(\frac{\text{section length}}{\text{average over all speed}} * \text{traffic volume} \right)$$

5.2. Calculating benefits

The snow removal deployment standard in Japan is snow accumulation depth of 5 to 10cm. So the benefits of snow removal are calculated according to the difference between the total travel time on LV.5, which is accumulated snow quantity of 10cm or higher, and total travel time at each point.

Benefits = total travel time (LV.5) – total travel time (LV.n)

6. CONCLUSIONS

This report presents the concept of a method of, based on the constant traffic volume observation data and snow accumulation and other meteorological observation data, analysing characteristics of road traffic by road surface condition by road conditions, finding the relationship between road conditions, road surface condition, QVK, and travel speed at each link of a road network in a snow accumulation region, and estimating the relationship of the management of road surface condition with the travel time reduction benefits of snow removal.
In the future, we will conduct research to develop a more precise method of calculating the benefits of snow removal by improving the precision of the quantitative relationship between travel speed and point speed in each section to apply the travel speed in each link.