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Analysis on Rural Highway Design using Traffic Micro-Simulation in Cold Regions

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Abstract

A sensitivity analysis was undertaken using a traffic flow micro-simulation program "SIM-R" to evaluate the effectiveness of "2+1 lane highway" sections, which were built by adding an auxiliary lane to rural two-lane highways, in a cold, snowy region. The road surface conditions analyzed were dry and covered with compacted snow. As evaluation indicators, average travel speed, the percentage of following vehicles and the density of following vehicles were used. As a result, the evaluation found that the installation of an auxiliary lane at certain intervals improved the level of service on two-lane highways.

Keywords; Service level, road surface condition, two-lane highways, "2+1 lane" highways, follower density

1. Introduction

Evaluating the performance of two-lane two-way highways is a complicated task due to their unique operating behaviors. On most highways, two lanes of traffic move in opposite directions; therefore, there are interactions between vehicles travelling in the same lane and those in the on-coming lane. For instance, drivers have to pass slower vehicles in front in order to maintain their desired speed. However, on two-lane highways, passing opportunities are limited. Accordingly, this type of road is characterized by the frequent formation of platoons of cars headed by low-speed vehicles.

Hokkaido is located in the northern part of Japan and covers an area of approximately 78,000km^2. The total length of national highways stretching over Hokkaido is 6,550 km. In terms of road structure, over 90% of national highways consist of two lanes. Hokkaido is a cold, snowy island, where winter, a season when snowfall is recorded, lasts for approximately five months from November to March. Therefore, road surfaces are usually dry but frequently covered with compacted snow. The running performance of vehicles deteriorates with an increase in traffic volume on dry road surfaces, and it further decreases on compacted-snow-covered road surfaces during winter.

On national highways in rural parts of Hokkaido, a measure to improve existing two-lane highways to "2+1 lane" highways by installing an auxiliary lane has been introduced to offer a better quality of service to road users.

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It is widely known that road improvement with the use of "2+1 lane" highways is further developed in European countries, including Sweden and Germany, as well as in the United States[1]. In order to efficiently evaluate the running performance and road structure of two-lane highways as well as "2+1 lane" highways, the creation of an appropriate traffic flow micro-simulation is demanded.

There have been studies on the evaluation of the structure of "2+1 lane highways" using traffic flow micro-simulation. Andreas Tapani[2] (2005) proposed a rural highway traffic flow micro-simulation called "RuTSim." This model incorporates a model of passing decision making on two-lane highways and consists of the four conditions: passing capability, surrounding traffic, possibility of passing by taking surrounding traffic into consideration, and road traffic regulations. Arne Carlsson and Andreas Tapani[3] (2006) used the RuTSim traffic flow simulation to evaluate the road structure of rural two-lane highways and "2+1 lane highways" in Sweden with average travel speed and the number of following vehicles used as major indicators to evaluate traffic flow. Other two-lane traffic flow simulations include the Two-Lane Passing (TEOPAS) model (Mc Lean 1989)[4] developed by the Midwest Research Institute and Traffic on Rural Roads (TRARR) (Hotban et al. 1991)[5] developed by the Australian Road Research Board. Unfortunately, there were no studies on traffic flow simulations that take into account weather and specific road surface conditions.

The authors developed a SIM-R traffic flow micro-simulation program to reproduce traffic flow responding to changes in road surface conditions. This program enables us to deal with changes in road surface conditions such as dry and compacted-snow-covered. The reproduction of traffic flow responding to changes in road surface conditions with the use of SIM-R was verified based on the field data collected at three sections of national highway in Hokkaido. Verification of the passing model and lane-changing model were carried out. This paper aims to reproduce the traffic flow of two-lane highways as well as "2+1 lane" highways using SIM-R traffic flow simulation and achieve the following objectives:

1) To evaluate the performance of "2+1 lane" road structure on dry and compacted-snow-covered road surfaces.
2) To clarify the validity of each of the following indicators: average travel speed, the follower percentage and the follower density.
3) To suggest an ideal road structure for national highways in cold, snowy regions Introduction

2. Indicators to evaluate the performance of two-lane highways

Roads provide drivers with service that should be smooth, comfortable, regular, reliable and safe. Indicators to evaluate the level of service from these various aspects have been developed. In the United States, the Highway Capacity Manual 2000 (HCM 2000)[6] published by the Transportation Research Board summarizes their views on the level of service. The HCM uses two factors – average travel speed (ATS) and percentage of time-spent-following (PTSF) – as indicators to evaluate the level of service on two-lane highways. The level of service is evaluated through the whole process, from planning and design to operation stages. In the planning and design stage, a decision is made on the number of lanes to be needed to achieve the target service level in consideration of design traffic volume. In the operation stage, a check is made to see whether the target service level has been met.

The previous study conducted by Brilon et al.[7] took up examples of rural two-lane highways in Germany and discussed the evaluation of highway performance based on German experiences. The previous study by Armed Al-Kaisy and Sarah Karjala[8] reviewed the literature on various indicators of performance of two-lane highways and discussed the advantage of each indicator. Taking these previous studies into account, this study decided to use the following performance indicators to evaluate the level of service of two-lane highways in order to provide easy-to-understand indicators for road users.

(1) Average travel speed

Average travel speed (ATS) is one of the two performance indicators used in the existing methodology by the HCM. This is expressed by the average speed of vehicles travelling over a certain section of roadway. Frequently used by transportation engineers, this indicator has the advantage of being easy to measure on site and easily understood by ordinary drivers.