講演番号 190

Study on CO_2 Reduction by Improving Traffic Flow

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KEY WORDS: **Social system, Traffic stream control, Traffic stream,** fuel consumption simulation [F1]

Toward the realization of carbon neutrality, in addition to vehicle-based measures, increasing attention has been paid to reducing CO_2 emissions through improvements in traffic flow. Under cruising conditions on expressways, differences in desired driving speeds among vehicles tend to induce catching-up and overtaking maneuvers, and the resulting acceleration and deceleration are considered to be one of the major factors contributing to increased CO_2 emissions.

This study focuses on cruising conditions on expressways and aims to quantitatively evaluate the CO_2 emission reduction effect of traffic flow smoothing achieved by reducing the width of the speed distribution within each lane.

To evaluate total CO_2 emissions in traffic flow, an evaluation framework was developed by combining a traffic flow simulation with fuel consumption simulations for passenger cars and heavy-duty vehicles (Fig.1). The traffic flow simulation reproduces catching-up and overtaking behaviors induced by differences in desired driving speeds among vehicles, as well as the associated acceleration and deceleration. In the fuel consumption simulations, CO_2 emissions are calculated based on the vehicle speed profiles, accounting for the increase in fuel consumption during acceleration and deceleration.

To evaluate changes in CO_2 emissions resulting from differences in speed distributions, two conditions, a current scenario and an ideal scenario, were compared. The evaluation was conducted for a 10-km section of the Shin-Tomei Expressway without merging or diverging areas, with a traffic volume of 1,070 vehicles per hour (690 passenger cars and 380 heavy-duty vehicles). In the current scenario, speed distributions based on observed data were used, whereas in the ideal scenario, a traffic flow state was assumed in which all vehicles traveled at the same speed within each lane and no lane changes occurred (Fig.2). In both scenarios, the average speed and traffic volume over the target section were kept identical.

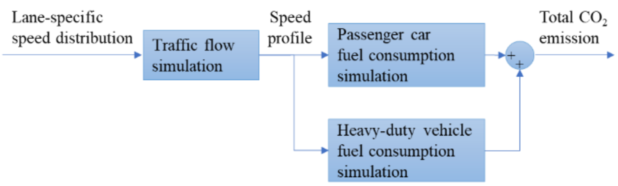

Fig.1 Simulation structure

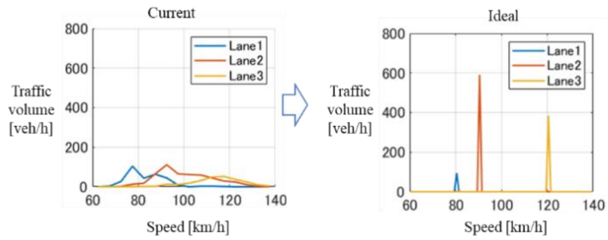

Fig.2 Speed distribution comparison

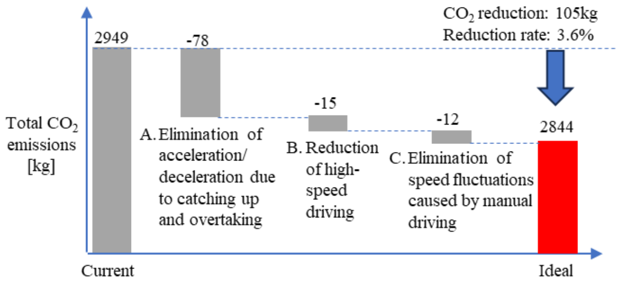

Fig.3 Breakdown of CO_2 reduction

In the ideal scenario, the total CO_2 emissions per hour for the target section decreased from 2,949 kg to 2,844 kg, corresponding to a reduction of 105 kg (3.6%). Contribution analysis revealed that the suppression of acceleration and deceleration associated with catching-up and overtaking accounted for approximately 74% of the total reduction, while the reduction in high-speed vehicles and the elimination of speed fluctuations caused by manual driving contributed additionally (Fig.3).

This study demonstrated that CO_2 emissions on expressways can be reduced through traffic flow smoothing by narrowing the width of the speed distribution without changing the average speed.

Future work will include investigating the amount of CO_2 emission reduction under various traffic conditions, such as different numbers of lanes, congestion levels, and the percentage of heavy-duty vehicles in the total traffic volume, as well as identifying which elements of the current speed distributions and overtaking behaviors should be prioritized for improvement from a more implementation-oriented perspective.