報告番号	※ 甲 第 10326 号

主 論 文 の 要 旨

論文題目 Analysis on Stochastic Characteristics of Breakdown Phenomena on Intercity Expressway Sections （都市間高速道路における渋滞現象の確率的特性に関する分析）

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論 文 内 容 の 要 旨

Analysis on breakdown phenomena is the base for various practical issues on intercity expressways at both the operational and the planning stages.

With respect to the operational stage, a macroscopic simulation platform is currently under construction which covers intercity expressway network of central Japan. It will enable evaluation of intercity expressway performance in response to traffic flow characteristics at the operational stage. As for development of this simulation platform, analysis on breakdown phenomena is a critical issue in light of their significant impacts on intercity expressway performance.

Furthermore, with respect to the planning stage, there exist the requirements for control on traffic condition characteristics, improvement on geometric configurations to alleviate breakdown phenomena. Again analysis on breakdown phenomena is desirable to quantify impacts of traffic condition and geometric characteristics.

To analyze breakdown phenomena, capacity of recurrent bottleneck will be focused on which includes two distinct aspects, namely breakdown flow rate and discharge flow rate. They impact on breakdown occurrence and its duration respectively. Both breakdown flow rate and discharge flow rate are characterized of stochastic natures which are influenced by traffic condition and geometric characteristics.

The objective of this study is to model breakdown flow rate and discharge flow rate by considering impacts of traffic condition characteristics and geometries on intercity expressways.

Chapter 1 describes significance of analyzing breakdown phenomena at recurrent bottlenecks for both the operational stage and the planning stages in practice. Then problem statement and objective of the study are presented. Finally, the research outline is generally reviewed.

Chapter 2 discusses the preparation for modeling breakdown and discharge flow rates. In-

tercity expressway network of central Japan is focused on where breakdown phenomena exist at diverge, merge and sag bottleneck locations which are identified based on flow rate-speed diagram of each detector. In light of its influence on breakdown occurrence, lane utilization rate (LUR) is modeled as a function of traffic condition and geometric characteristics.

In Chapter 3, a lane based method is proposed to identify breakdown occurrence. The existing cross-section based method oversimplifies breakdown identification for bottlenecks at expressway facilities where lane usage preferences on each lane significantly differ like nearby diverge and merge sections. Therefore, a lane based method is proposed to identify breakdown on each lane. And timing of breakdown occurrence is determined by a critical speed which is optimized through obtaining the most significant speed drops accompanying with breakdown occurrences.

The proposed lane based method is applied to diverge and merge bottlenecks. Superiorities of lane based method are highlighted as follows. Firstly, it can identify and exclude semi-congested cases where some lanes are congested and others are not. Secondly, timing of breakdown occurrence can be appropriately determined through this lane based method. These superiorities significantly improve the accuracy of extracting breakdown flow rates which are underestimated by the existing cross-section based method.

In Chapter 4, breakdown probability models are developed. At diverge and merge bottlenecks, modeling is based on the identification results by using lane based method as described in chapter 3. Besides lane utilization rate, diverge rate and merge rate are also found to have significant impacts on breakdown probability at diverge and merge bottlenecks respectively. With respect to sag bottlenecks, the general breakdown probability model is established by considering impacts of site-specific geometries of negative and positive slopes.

As for practical application in simulation, the models enable estimation of breakdown occurrence at the operational stage. Estimation accuracy can be improved by taking traffic condition characteristics into account. In addition, consideration of geometric characteristics enables the estimation of potential bottleneck.

Chapter 5 introduces modeling on discharge flow rate in a stochastic way. Breakdown flow rate and the elapsed time of breakdown duration are found to have significant impacts on discharge flow rate which are taken into consideration when modeling. In addition, the general discharge flow rate models are established respectively for each bottleneck type. At diverge and merge bottlenecks, site-specific deceleration and acceleration lane lengths are taken into account when generalizing DCF model respectively. With respect to sag bottleneck, site-specific geometries of negative and positive slopes are considered.

With respect to practical application in simulation, the developed stochastic DCF models enable the performance evaluation for breakdown duration in a stochastic way. Advantages of the developed models are highlighted as follows which improve evaluation accuracy. The relationship between breakdown and discharge flow rates is taken into account. Further-

more, a descending tendency of discharge flow rate is modeled with increase of elapsed time of breakdown duration.

Chapter 6 discusses simulation of breakdown phenomena by using the developed breakdown probability and discharge flow rate models. Simulation is performed through Monte Carlo method in the way as follows: 1) breakdown flow rates are stochastically generated by using breakdown probability models, and then 2) discharge flow rate distributions are reproduced based on input of breakdown flow rate values. The simulated number of breakdown occurrence, time-dependent frequency and breakdown duration are adopted as performance measure to evaluate simulation. The investigation in this chapter verifies the effectiveness of the developed models for simulation in practice.

Chapter 7 introduces the case study by applying the developed stochastic models. The selected test bed is located on Tomei Expressway of westbound direction from Okazaki IC to Toyota JCT. With respect to test bed, the map of breakdown probability distributions is developed considering impacts of traffic flow characteristics. This kind of map enables the estimation on the risk of breakdown occurrence due to change of traffic condition characteristics.

Finally, Chapter 8 summarizes research conclusions and provides some recommendations for future research. Most of all, the breakdown and discharge flow rates are modeled which enables simulation of breakdown phenomena at the operational stage. Also these models offer the base for improvement on geometric configurations to alleviate breakdown phenomena at the planning stage.

Furthermore, it is concluded that lane based method is superior over the conventional cross-section based method for breakdown identification at diverge and merge bottlenecks. For example, it significantly improve accuracy of extracting breakdown flow rates by 2.6 % which are underestimated by the existing cross-section based method at Toyota diverge bottleneck.

Meanwhile traffic condition characteristics have been taken into consideration when modeling which improves estimation accuracy of breakdown probability. At Toyota diverge bottleneck, estimation accuracy can be improved by 20.5 % when reproducing breakdown phenomena there. In addition, map of breakdown probability distribution enables evaluation of breakdown occurrence at the operational stage for users.