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Author(s)	段, 開峰
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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称 博士（工学） 氏名 段 開峰

学 位 論 文 題 名

Development of efficient solution algorithms based on sensitivity analysis for network
design problems with user equilibrium constraints

(利用者均衡制約付ネットワークデザイン問題に対する感度分析に基づく効率的解法の
開発)

Network Design Problems (NDPs) are essential for optimizing infrastructure and resource allocation in transport networks. A key challenge in solving NDPs arises from equilibrium constraints, e.g., the user equilibrium (UE) principle. The inclusion of UE constraints in NDPs reflects the real-world dynamics of travelers' behavior in transport networks, where travelers adjust their path choices in response to changes of path cost in the network, seeking to minimize their travel costs. Incorporation of UE constraints makes NDPs computationally intensive to solve, as each network adjustment requires reevaluation of the equilibrium state. To address this issue, this dissertation proposes efficient solution algorithms based on sensitivity analysis to improve the computational efficiency in solving NDPs with UE constraints. By using sensitivity analysis, the proposed algorithms effectively evaluate how changes in network parameters influence the equilibrium state. The algorithms enable a more simplified iteration process, significantly reducing the computational burden while maintaining the accuracy of the results.

This thesis is organized into 7 chapters. Chapter 1 describes the background and purpose of this thesis. Chapter 2 describes the existing research and basic models used in this study.

Chapter 3 proposes a computationally efficient algorithm based on the sensitivity analysis of UE for solving a traffic state estimation problem by using floating car data. The traffic states in a road network are obtained by solving a full information maximum likelihood estimation (FIMLE) problem under UE constraints. Solving the FIMLE problem under equilibrium constraints requires much computations time. Therefore, an efficient solution algorithm is needed. The traffic states in the Asahikawa network in Hokkaido, Japan estimated by the algorithm are presented in Chapter 4.

Chapter 5 proposes a bi-level programming model to solve an optimization problem of bus

route settings and service frequencies, in road networks where connected and autonomous buses (CABs) are introduced as a public transport system. The upper-level problem is formulated as a discrete optimization problem, which is then relaxed into a continuous form. A nonlinear optimization algorithm is applied to solve this problem. This optimization problem is subject to user equilibrium constraints at the lower level, represented by the UE principle. An algorithm based on the sensitivity analysis method is developed for solving the bi-level model. Numerical examples and results are shown in Chapter 6.

In conclusion, this thesis develops innovative algorithms to enhance the computational efficiency and practical applicability of NDPs with the UE constraints. These algorithms were successfully applied in Chapter 4 to estimate traffic states in the real-world network of Asahikawa, Hokkaido, Japan, and in Chapter 6 to solve the optimization problem of bus route settings and service frequencies in Sioux Falls network. These findings demonstrate the capability of the proposed algorithm to effectively address the challenges of computational efficiency and practical implementation in NDPs with UE constraints.