國 立 交 通 大 學
運輸科技與管理學系

博士論文

路網流量逐日演變之研究－在智慧型運輸系統運作情境下

Day-to-day Network Flow Evolution under Intelligent Transportation Systems

研 究 生：黃銘崇 撰著

指導教授：卓訓榮 博士

中華民國九十三年四月

Day-to-day Network Flow Evolution under Intelligent Transportation Systems

Graduate: Ming-Chorng Hwang   Advisor: Prof. Hsun-Jung Cho

Dissertation Submitted to
Department of Transportation Technology and Management
College of Management
National Chiao Tung University

in Partial Fulfillment of the Requirement for the Degree of

DOCTOR OF PHILOSOPHY

April, 2004

Hsinchu, Taiwan, Republic of China

路網流量逐日演變之研究－在智慧型運輸系統運作情境下

學生：黃銘崇　　　　　　　　　　　　　　　　指導教授：卓訓榮

國立交通大學運輸科技與管理學系

摘 要

在智慧型運輸系統(Intelligent Transportation Systems)運作情境下，運輸資訊提供與用路人之間的互動行為是影響智慧型運輸系統能否發揮效能與效率的重要因素之一，因此，不論是實務上的交通營運管理分析或是學術上的理論性研究，如何描述與預測這個互動行為及其所對應產生的路網流量演變(evolution)便成為一個很重要的課題。

本研究即是在智慧型運輸系統運作情境下，基於「追求最小旅行時間行為假設」，及過去研究中曾實際被觀察到通勤性用路人的「逐日學習與適應性的旅運決策行為假設(day-to-day learning and adaptive behavioral assumption)」，提出「路網流量逐日演變與運輸資訊提供的互動理論」，這個理論包含路徑流量演變(path flow dynamics)、預測最小旅行時間演變(predicted minimal travel time dynamics)與這兩者的互動關係。

「路徑流量演變理論」描述用路人在接收智慧型運輸系統提供充分的路徑資訊與預測最小旅行時間後，經由逐日學習與適應演變的行為假設，進而造成路徑流量的演變。「預測最小旅行時間演變」則說明智慧型運輸系統如何經由每日實際偵測的路徑流量，同樣以學習與適應的方式預測其每日的最小旅行時間。

此外，本研究以動態系統方法(dynamical system approach)構建這個理論的數學模式，由模式的穩態(steady state)分析發現，這個數學模式的均衡解(equilibrium solution)滿足 Wardrop 使用者均衡(user equilibrium)的原則。經由微分方程理論的基本定理(the fundamental theorem of differential equations)，本研究提出一個輔助定理(Lipschitz lemma)證明這個數學模式滿足微分方程的基本定理，進而確認其解的存在性與唯一性(existence and uniqueness)。本研究同時也應用 Lyapunov 穩定性定理(Lyapunov stability theorem)，證明這個數學模式的均衡解是漸進穩定的(asymptotic stable)。

Day-to-day Network Flow Evolution under Intelligent Transportation Systems

Student：Ming-Chorng Hwang Advisor：Hsun-Jung Cho

Department of Transportation Technology and Management
National Chiao Tung University

Abstract

The interaction between information provision and the corresponding response of users is an important feature to functionalize the effectiveness and efficiency of ITS operations. Therefore, the ability of predicting how the travel information predicted and provided by ITS influences the time trajectory of network flows is an essential issue both in the viewpoints of theoretical analysis and in that of traffic operational improvements.

This dissertation develops a new theory of day-to-day network dynamics capable of characterizing the inter-dependence between travel information provision and network evolution with the behavioral assumptions of minimal travel time seeking and daily learning and adaptive process under the scenario of ITS services. The structure of the proposed theory includes path flow dynamics, predicted minimal travel time dynamics, and their inter-relationships

Under the two behavioral assumptions mentioned above, the theory of path flow dynamics describes the mechanism of path flow evolution resulted from the provision of path information and predicted minimal travel time by ITS services. The theory of predicted minimal travel time specifies how the minimal travel time is predicted from the detected path volumes by ITS in a origin-destination pair standpoints.

In addition, the author constructs a mathematical model for the theory by using dynamical system approach. The steady state of the model satisfies the Wardrop's user equilibrium. The analysis of existence and uniqueness is also derived by the Lipschtitz lemma and the fundamental theorem of differential equations. Finally, a strict Lyapunov function is established to give the asymptotic stability for the equilibrium solution of the proposed model in the sense of Lyapunov stable.

Acknowledgements

I would like to express my sincere gratitude to professor Hsin-Jung Cho for his guidance, patience, and encouragement in both academic and personal life throughout my Ph.D. study.

I am very grateful to Prof. Tsu-Tian Lee, Prof. Heuy-Kuo Chen, Prof. Hsin-Li Chang, and Prof. Anthony F. Han, members of the dissertation committee, for their great guidance and comments. Moreover, I am in debt to Prof. Gang-Len Chang for the valuable communication of his research experiences in day-to-day network dynamics.

This dissertation is partly sponsored by the Program for Promoting University Academic Excellence, Ministry of Education, Taiwan R.O.C., through the contract EX-91-E-FA06-4-4 entitled "Intelligent Transportation Systems – Human Centered Technology".

Finally, I am deeply appreciated to my parents for their endless supports. And I would like to thank Miss Jacqui Jow for her sincere encouragement and friendship. In particular, I would also like to thank my sister, Sera Hwang, and her husband, Bill Bao, for their very generous kindness and financial aid during my Ph.D. research career in Hsinchu.

Contents

List of Figures

List of Tables