

ABSTRACT

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William H.K. LAM, S.C. WONG, Hong K. LO

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Department of Civil and Structural Engineering
The Hong Kong Polytechnic University

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Chapter 1

A Game Theoretic Approach to the Determination of Hyperpaths in Transportation Networks

Jan-Dirk Schmöcker, Tokyo Institute of Technology, Japan; Michael G.H. Bell, Imperial College London, U.K.; Fumitaka Kurauchi, Gifu University, Japan; Hiroshi Shimamoto, Hiroshima University, Japan

In transit assignment, the common lines problem leads to the notion of a hyperpath, which is a set of paths that when used according to the “take whichever attractive line arrives next” strategy minimises the expected travel time. Similarly, the game theoretic approach to risk-averse traffic assignment leads to the generation of a set of paths which minimises expected travel time when a pessimistic assumption is made about on-trip events. The equivalence between the hyperpath of transit assignment and the set of paths generated by a multi-agent, zero sum game is shown in this paper. In particular, game theory is used to show that the path split probabilities proposed by Spiess and Florian (1989) are optimal for the risk-averse traveller who needs to make an on-the-spot decision between alternative routes. An alternative two-agent (single demon), zero-sum game is considered. The results of the multiple- and two-agent games are compared on a small example network, showing that the single demon game can lead to denser hyperpaths.

Chapter 2

Network Equilibrium under Cumulative Prospect Theory and Endogenous Stochastic Demand and Supply

Agachai Sumalee, The Hong Kong Polytechnic University, Hong Kong; Richard D. Connors, University of Leeds, U.K.; Paramet Luatkep, The Hong Kong Polytechnic University, Hong Kong

In this paper we consider a network whose travel demands and road capacities are endogenously considered to be random variables. With stochastic demand and supply the route travel times are also random variables. In this scenario travelers choose their routes under travel time uncertainties. Several evidences suggest that the decision making process under uncertainty is significantly different from that without uncertainty. Therefore, the paper applies the decision framework of cumulative prospect theory (CPT) to capture this difference. We first formulate a stochastic network model whose travel demands and link capacities follow lognormal distributions. The stochastic travel times can then be derived under a given route choice modeling framework. For the route choice, we consider a modeling framework where the perceived value and perceived probabilities of travel time outcomes are obtained via transformations following CPT. We then formulate an equilibrium condition similar to that of User Equilibrium in which travelers choose the routes that maximizes their perceived utility values in the face of transformed stochastic travel times. Conditions are established guaranteeing existence (but not uniqueness) of this equilibrium. The paper then proposes a solution algorithm for the proposed model which is then tested with a test network.

Chapter 3

Estimation of Parameters of Network Equilibrium Models: A Maximum Likelihood Method and Statistical Properties of Network Flow

Shoichiro Nakayama, Kanazawa University, Japan and University of Leeds, U.K.; Richard D. Connors and David Watling, University of Leeds, U.K.

Estimation of the parameters in network equilibrium models, including OD matrix elements, is essential when applying the models to real-world networks. Link flow data are convenient for estimating parameters because it is relatively easy for us to obtain them. In this study, we propose a maximum likelihood method for estimating parameters of network equilibrium models using link flow data, and derive first and second derivatives of the likelihood function under the equilibrium constraint. Using the likelihood function and its derivatives, t -values and other statistical indices are provided to examine the confidence interval of estimated parameters and the model's goodness-of-fit. Also, we examine which conditions are needed for consistency, asymptotic efficiency, and asymptotic normality for the maximum likelihood estimators with non-I.I.D. link flow data. In order to investigate the validity and applicability, the proposed ML method is applied to a simple network and the road network in Kanazawa City, Japan.

Chapter 4

Spatiotemporal Effects of Segregating Different Vehicle Classes on Separate Lanes

Michael J. Cassidy, Carlos F. Daganzo and Kitae Jang, University of California, U.S.A.; Koohong Chung, California Department of Transportation, U.S.A.

The paper explores some of the impacts of setting aside road lanes for the exclusive use of select vehicle classes. We examine first the case of lanes that are reserved for carpools, and then extend the analysis to bus-only lanes. In doing so, the paper makes three contributions. The first is methodological: it illustrates the importance of analyzing freeway data in full spatiotemporal detail. The second is physical: data reveal that carpool lanes are not as damaging as previously reported. In fact, these lanes are found to smooth traffic in adjacent lanes so much (by diminishing disruptive vehicle interactions near bottlenecks) that even substantially underutilized carpool lanes can increase bottleneck discharge flows. The third contribution is theoretical: it uses the smoothing phenomenon to show how the judicious deployment of bus-only lanes on freeways and city streets can favorably affect not just buses, but also cars.

Chapter 5

Microscopic Traffic Behaviour near Incidents

Victor L. Knoop, Henk J. van Zuylen and Serge P. Hoogendoorn, Delft University of Technology, The Netherlands

Much of the delays on road networks are caused by incidents. This is partially caused by blockage or closure of lanes, but also by the change of driving behaviour in the remaining lanes. This contribution analyses traffic flow conditions near an incident both microscopically and macroscopically. A theory is proposed to describe drivers' behaviour, which is tested using traffic data of individual vehicles, collected using a helicopter. A bimodal headway distribution is observed, centred around two mean values, 2 seconds and 4 seconds. To understand the underlying mechanisms a car-following model is fitted to the drivers' behaviour. The model parameters show that the reaction time is much higher than usual. Using this model-based analysis, we conclude that the incident distracts the drivers and less attention is paid to the driving process. The consequence is that the queue discharge rate for the unblocked lanes is 30% lower than the usual queue discharge rate per lane.

Chapter 6

Understanding Stop-and-go Traffic in View of Asymmetric Traffic Theory

Hwasoo Yeo and Alexander Skabardonis, University of California, U.S.A.

Stop-and-go traffic is a frequently observed phenomenon in congested highway traffic, but it has not been accurately modeled in existing traffic models. Car-following models based on kinematic flow theory cannot model stop-and-go traffic. Other approach assumed traffic states deviating from the equilibrium curve in the fundamental diagram, and the transitions between them, but no explanation was provided on the reason for the existence of different states. There is a need to understand the mechanism of stop-and-go traffic in terms of generation, propagation and dissipation in order to accurately model traffic dynamics. We propose an asymmetric traffic theory and explain the stop-and-go traffic phenomenon in light of the developed theory. The proposed theory is verified using individual vehicle trajectories from two freeway sites in California, US, collected as part of the Next Generation Simulation (NGSIM) project.

Chapter 7

A Stochastic α -reliable Mean-excess Traffic Equilibrium Model with Probabilistic Travel Times and Perception Errors

Anthony Chen, Utah State University, U.S.A.; Zhong Zhou, Citilabs, U.S.A.

This paper proposes a novel stochastic mean-excess traffic equilibrium model that considers both reliability and unreliability aspects of travel time variability and perception errors within the travelers' route choice decision processes. In the model, each traveler not only considers a travel time budget for ensuring on-time arrival at a confidence level α , but also accounts for the impact of encountering worst travel times in the $(1-\alpha)$ quantile of the distribution tail. Furthermore, due to the imperfect knowledge of the travel time variability, the travelers' route choice decisions are based on the *perceived* travel time distribution rather than the actual travel time distribution. In order to compute the *perceived* mean-excess travel time, an approximation method based on moment analysis is developed. The proposed model is formulated as a variational inequality (VI) problem, and solved by a route-based solution algorithm with the use of the modified alternating direction method. Numerical examples are also provided to illustrate the application of the proposed model and solution method.

Chapter 8

Equilibrium Trip Scheduling in Congested Traffic under Uncertainty

Barbara W.Y. Siu and Hong K. Lo, The Hong Kong University of Science and Technology, Hong Kong

Whilst traditional modeling and research efforts put emphasis on the effect of congestion on travel choices, recently more and more studies examine the notion of travel time uncertainty on travel decision. In particular, travel time reliability forms an important component in modeling route choice and trip scheduling. This paper considers equilibrium trip scheduling under random travel delay in a single bottleneck. Travelers form a heterogeneous population with distinctive requirements on the probability of punctual arrival and each with a different valuation toward earliness and lateness. The analysis shows that random delay plays a significant role in travel costs and introduces substantial differences in the queuing pattern, departure and arrival times, as compared with the traditional deterministic model.

Chapter 9

Reliable a Priori Shortest Path Problem with Limited Spatial and Temporal Dependencies

Yu (Marco) Nie and Xing Wu, Northwestern University, U.S.A.

This paper studies the problem of finding most reliable a priori shortest paths (RASP) in a stochastic and time-dependent network. Correlations are modeled by assuming the probability density functions of link traversal times to be conditional on both the time of day and link states. Such correlations are spatially limited by the Markovian property of the link states, which may be such defined to reflect congestion levels or the intensity of random disruptions. We formulate the RASP problem with the above correlation structure as a general dynamic programming problem, and show that the optimal solution is a set of non-dominated paths under the first-order stochastic dominance. Conditions are proposed to regulate the transition probabilities of link states such that Bellman's principle of optimality can be utilized. We prove that a non-dominated path should contain no cycles if random link travel times are consistent with the stochastic first-in-first-out principle. The RASP problem is solved using a non-deterministic polynomial label correcting algorithm. Approximation algorithms with polynomial complexity may be achieved when further assumptions are made to the correlation structure and to the applicability of dynamic programming. Numerical results are provided.

Chapter 10

Risk Averse Second Best Toll Pricing

Xuegang (Jeff) Ban, Rensselaer Polytechnic Institute, U.S.A.; Shu Lu, University of North Carolina at Chapel Hill, U.S.A.; Michael Ferris, University of Wisconsin-Madison, U.S.A.; Henry X. Liu, University of Minnesota, U.S.A.

Existing second best toll pricing (SBTP) models determine optimal tolls of a subset of links in a transportation network by minimizing certain system objective, while the traffic flow pattern is assumed to follow user equilibrium (UE). We show in this paper that such toll design approach is risk prone, which tries to optimize for the best-case scenario, if the UE problem has multiple solutions. Accordingly, we propose a risk averse SBTP approach aiming to optimize for the worst-case scenario, which can be formulated as a *min-max* problem. We establish a general solution existence condition for the risk averse model and discuss in detail that such a condition may not be always satisfied in reality. In case a solution does not exist, it is possible to replace the exact UE solution set by a set of approximate solutions. This replacement guarantees the solution existence of the risk averse model. We then develop a scheme such that the solution set of an affine UE can be explicitly expressed. Using this explicit representation, an improved simplex method can be adopted to solve the risk averse SBTP model.

Chapter 11

Cordon Pricing Consistent with the Physics of Overcrowding

Nikolas Geroliminis and David M. Levinson, University of Minnesota, U.S.A.

This paper describes the modeling of recurring congestion in a network. It is shown that the standard economic models of marginal cost cannot describe precisely traffic congestion in networks during time-dependent conditions. Following a macroscopic traffic approach, we describe the equilibrium solution for a congested network in the no-toll case. A dynamic model of cordon-based congestion pricing (such as for the morning commute) for networks is developed consistent with the physics of traffic. The paper combines Vickrey's theory with a macroscopic traffic model, which is readily observable with existing monitoring technologies. The paper also examines some policy implications of the cordon-based pricing to treat equity and reliability issues, i.e. in what mobility level a city should choose to operate. An application of the model in a downtown area shows that these schemes can improve mobility and relieve congestion in cities.

Chapter 12

Build-operate-transfer Schemes for Road Franchising with Road Deterioration and Maintenance Effects

Zhijia Tan, Hai Yang and Xiaolei Guo, The Hong Kong University of Science and Technology, Hong Kong

Private provision of public roads through build-operate-transfer (BOT) approaches is increasing around the world. By considering both social welfare gain and profitability, the BOT problem is to determine the optimal BOT contract which can be viewed as a combination of three primary variables of concession period, road capacity and toll charge. This paper models the BOT problem as the isoperimetric problem in calculus of variations to maximize the social welfare with a profit constraint. The model explicitly incorporates the effect of road deterioration and maintenance over the years, which is assumed to depend on the traffic loads, road capacity and road natural deterioration. We find that an optimal pricing policy requires toll increase over calendar time to reduce traffic load due to time-increasing and load-increasing maintenance cost. If, however, the marginal user damage on road is independent of time, then the optimal toll charge is free from the effect of road natural deterioration and thus time-invariant. We also discuss how to reach an optimal contract through government regulations and investigate the effects of economic growth on the solution properties of the problem.

Chapter 13

Equilibria and Inefficiency in Traffic Networks with Stochastic Capacity and Information Provision

Tian-Liang Liu and Hai-Jun Huang, Beijing University of Aeronautics and Astronautics, China; Hai Yang and Xiaolei Guo, The Hong Kong University of Science and Technology, Hong Kong

In this paper, we study the inefficiencies of various behavior equilibria in traffic networks with stochastic capacity and information provision. Variational inequality models are presented to formulate the travel behaviors associated with user equilibrium (UE) with imperfect information, system optimum (SO) with imperfect information and system optimum with perfect information, respectively. The tight upper bounds of inefficiencies caused by UE selfish behavior with imperfect information are analytically discussed in detail. It is found that when link travel time functions are all polynomial, the worst-case inefficiencies against the SOs with imperfect or perfect information are dependent upon the steepness degree of link time functions and independent of the network topology. The upper bound of inefficiency against the SO with perfect information is yet dependent upon the degradation degree and occurring probability density of link capacity. Furthermore, it is also found that perfect information can always improve the traffic network performance whilst imperfect information has the same worst-case efficiency as zero information.

Chapter 14

An Active-set Algorithm for Discrete Network Design Problems

Lihui Zhang, Siriphong Lawphongpanich and Yafeng Yin, University of Florida, U.S.A.

In this paper, we formulate a discrete network design problem as a mathematical program with complementarity constraints and propose an active set algorithm to solve the problem. Each complementarity constraint requires the product of a pair of nonnegative variables to be zero. Instead of dealing with this type of constraints directly, the proposed algorithm assigns one of the nonnegative variables in each pair a value of zero. Doing so reduces the design problem to a regular nonlinear program. Using the multipliers associated with the constraints forcing nonnegative variables to be zero, the algorithm then constructs and solves binary knapsack problems to make changes to the zero-value assignments in order to improve the system delay. Numerical experiments with data from networks in the literature indicate that the algorithm is effective and has the potential for solving larger network design problems.

Chapter 15

Multi-class Multi-modal Network Equilibrium with Regular Choice Behaviors: A General Fixed Point Approach

Meng Xu and Ziyou Gao, Beijing Jiaotong University, China

In this paper, we propose a new model for the multi-class multi-modal network equilibrium problem, which is a route utility based model, and transfer flows for combined modes are considered specially. The model is formulated as a general fixed point problem. The choice behaviors are assumed regular, which include the common features of deterministic and of continuous with continuous first derivatives additive probabilistic choice models. Users of different classes permit different choice behaviors (including routes, modes, and interchanges), as well as different sets of available routes, modes, and interchanges. Different choice models are explicitly considered; in addition, travel demand of the network can be dealt without using its inverse-unlike the mathematical programming, variational inequality, or complementarity formulations. Existence and uniqueness of the model are analyzed, which extend those conclusions in existed literature.

Chapter 16

Existence of Equilibrium in a Continuous Dynamic Queueing Model for Traffic Networks with Responsive Signal Control

Richard Mounce, Queen's University, U.K.

Many real-life traffic systems incorporate responsive traffic signal control, i.e. where the green time assigned to a stage at a junction depends on the queue lengths on the various approaches. By making signals responsive one might expect the queueing pattern to approach equilibrium, i.e. a queueing pattern for which the responsive policy tells us to leave the signal settings unchanged. However, changing junction signal settings changes the costs of traversing the approaches to the junction and traffic may change route in the light of this. Hence, a responsive signal system is really at equilibrium only if it is at equilibrium with respect to its own rules and also with respect to the re-routing of traffic. The paper gives a framework for responsive signal control in the dynamic queueing model in terms of stage pressures. Three responsive signal policies are considered: delay-minimisation, equisaturation and P_0 . A dynamical system is specified that describes both changes to signals due to the responsive signal policy and changes to route inflows due to the re-routing of traffic. An implicit function theorem is utilised in showing that the swap vector for the dynamical system is a continuous function of the route flow vector and green time vector. Then by Schauder's fixed point theorem, there exists equilibrium of the dynamical system. Finally, the responsive policies are compared with fixed signals in network simulations.

Chapter 17

Harmonic Analysis and Optimization of Traffic Signal Systems

Nathan H. Gartner and Rahul Deshpande, University of Massachusetts Lowell, U.S.A.

This paper develops applications of harmonic analysis for traffic signal performance evaluation and optimization. Link Performance Functions in synchronized signal networks measure delay or travel time as a function of offsets. They depend on a variety of factors, including: traffic flow characteristics, link physical characteristics, and traffic signal controls. Being periodic with the cycle time they can be modeled as a **Fourier Series** which is an expansion of a periodic function $f(x)$ in terms of a sum of sines and cosines. Just a few harmonics can provide good approximations to the original functions. The paper shows how to derive the principal harmonics in terms of the underlying traffic, link and signal data. This enables one to construct a simple and very effective model for analysis, optimization and control. The paper proceeds to apply this model in two cases. The first case involves performance estimation of signal controlled intersections for planning and design purposes. The second case develops a novel Dynamic Programming optimization model which provides a rigorous procedure for signal coordination and synchronization.

Chapter 18

A Two-direction Method of Solving Variable Demand Equilibrium Models with and without Signal Control

Mike Smith, University of York, U.K.

A two direction method of solving variable demand equilibrium models is considered. Throughout an equilibration using this method, if the first direction fails to reduce disequilibrium, use the second. A proof of convergence under fairly weak conditions is provided. The paper shows how the method works on models without and with responsive signal controls. In the former case the method may replace the iteration of an assignment and a demand model. In the latter case the method may replace the iteration of an assignment and a control model; and may then be utilized to design new fixed time signal timings suitable for a variety of situations. In both cases there will be a reasonable convergence guarantee if the two-direction method is utilized.

Chapter 19

Modeling Learning Impacts on Day-to-day Travel Choice

Ozlem Yanmaz-Tuzel and Kaan Ozbay, Rutgers University, U.S.A.

This paper uses Stochastic Learning Automata and Bayesian Inference theory to model drivers' day-to-day learning behavior in an uncertain environment. The proposed model addresses the adaptation of travelers on the basis of experienced choices and user-specific characteristics. Using the individual commuter data obtained from New Jersey Turnpike, the parameters of the model are estimated. The proposed model aims to capture the commuters' departure time choice learning/adaptation behavior under disturbed network conditions (after toll change), and to investigate commuters' responses to toll, travel time, departure/arrival time restrictions while selecting their departure times. The results have demonstrated the possibility of developing a psychological framework (i.e., learning models) as a viable approach to represent travel behavior.

Chapter 20

A Probit-based Joint Discrete-continuous Model System: Analyzing the Relationship between Timing and Duration of Maintenance Activities

Xin Ye, University of Maryland, U.S.A.; Ram M. Pendyala, Arizona State University, U.S.A.

This paper presents a probit-based discrete-continuous modeling methodology to analyze relationships between discrete and continuous choice dimensions often encountered in activity-travel behaviour research. The probit-based approach allows one to adopt a flexible multivariate normally distributed error covariance structure that overcomes the limitations associated with other discrete-continuous modeling methods that rely on two-step limited information techniques or restrictive distributional transformations. The paper presents the detailed formulation of the modeling methodology and demonstrates its applicability through an analysis of the relationship between the timing (scheduling) and duration of household maintenance activities that include shopping and personal business activity episodes. A new non-nested test developed by the authors is used to compare alternative model structures and identify the nature of the joint relationship between the timing and duration of maintenance activities. Models are estimated separately for commuter and non-commuter samples drawn from the 2000 Switzerland Microcensus of Travel. Model estimation results show that error covariances are significant for commuter models of maintenance activity timing and duration. Non-nested model comparisons indicate that the model specification where time-of-day choice affects activity duration offers a statistically superior goodness-of-fit in comparison to the model specification where activity duration affects time-of-day choice. These findings lend credence to the notion that the joint relationship between timing and duration adopted in activity-based model systems should be one in which the activity schedule or agenda drives activity time allocation or duration.

Chapter 21

Bayesian Learning, Day-to-day Adjustment Process, and Stability of Wardrop Equilibrium

Shoichiro Nakayama, Kanazawa University, Japan and University of Leeds, U.K.

In this study, we assume that drivers under day-to-day dynamic transportation circumstances choose routes based on Bayesian learning and develop a day-to-day dynamic model of network flow. This model reveals that a driver using Bayesian learning chooses the route that frequently takes the minimum travel time. Furthermore, we find that the equilibrium point of the day-to-day dynamic model is identical to Wardrop's equilibrium. Under complete information (when information about which route takes the minimum travel time is given after the trips), Wardrop's equilibrium is globally asymptotically stable and the day-to-day dynamic system converges to Wardrop's equilibrium if initial recognition among drivers is distributed widely. Under incomplete information, Wardrop's equilibrium is always globally asymptotically stable regardless of what the drivers' initial recognition is. Paradoxically, the condition for stable equilibrium under incomplete information is more relaxed than that under complete information.

Chapter 22

Hotspot Identification: A Full Bayesian Hierarchical Modeling Approach

H.L. Huang, University of Central Florida, U.S.A.; H.C. Chin and M.M. Haque, National University of Singapore, Singapore

This study proposes a full Bayes (FB) hierarchical modeling approach in traffic crash hotspot identification. The FB approach is able to account for all uncertainties associated with crash risk and various risk factors by estimating a posterior distribution of the site safety on which various ranking criteria could be based. Moreover, by use of hierarchical model specification, FB approach is able to flexibly take into account various heterogeneities of crash occurrence due to spatiotemporal effects on traffic safety. Using Singapore intersection crash data (1997-2006), an empirical evaluate was conducted to compare the proposed FB approach to the state-of-the-art approaches. Results show that the Bayesian hierarchical models with accommodation for site specific effect and serial correlation have better goodness-of-fit than non-hierarchical models. Furthermore, all model-based approaches perform significantly better in safety ranking than the naive approach using raw crash count. The FB hierarchical models were found to significantly outperform the standard EB approach in correctly identifying hotspots.

Chapter 23

The Continuous Risk Profile Approach for the Identification of High Collision Concentration Locations on Congested Highways

Koohong Chung, California Department of Transportation, U.S.A.; David R. Ragland, Samer Madanat and Soon Mi Oh, University of California, U.S.A.

This paper documents a new method for monitoring traffic collision data from continuous roadway facilities to detect high collision concentration locations. Many existing methods for detecting collision concentration locations require segmentation of roadways and assume traffic collision data are spatially uncorrelated, resulting in both false positives (i.e., identifying sites for safety improvements that should not have been selected) and false negatives (i.e., not identifying sites that should have been selected). The proposed method does not require segmentation of roadways; spatial correlation in the collision data does not affect the results of analysis. This new method has a lower false positive rate than the conventional sliding moving window approach. This paper shows how the proposed method can proactively identify high collision concentration locations and capture the benefit of safety improvements observed in the project location and in neighboring sites.

Chapter 24

Driver Behavior, Dilemma Zone, and Capacity at Red Light Camera Equipped Intersections

Yohannes Weldegiorgis and Manoj K. Jha, Morgan State University, U.S.A.

Driver behavior at an intersection equipped with a Red Light Camera (RLC) is one of the main factors contributing to the safety and operation of the intersection. A drivers' decision whether to proceed through the intersection or stop when the signal changes from green to yellow depends on a number of factors, such as speed, geometric characteristics, driver's attitude, to name a few. The decision with respect to the yellow signal may lead to traffic conflicts such as rear end and right angle collisions. Driver behavior when faced with a yellow signal can be viewed as a binary choice process, where the main decisions are either to stop or proceed through the intersection. In this paper, a discrete choice model of the stopping probability is developed using vehicles' speed and distance from the stop bar when the driver is exposed to the yellow signal. A binary choice model is developed using the probability of stopping to the yellow signal as a function of approach speed, distance from intersection, and presence of a RLC. The existence of the Dilemma Zone (DZ) is estimated using dilemma zone curves developed from the probability of stopping vs. distance from stop bar at the onset of the yellow interval. The paper also presents a new approach to calculate the change in intersection capacity resulting from drivers stopping at the intersection at the onset of yellow interval. Using field data from Baltimore, Maryland we show that the capacity of RLC equipped intersections may be lower than that at intersections without RLC.

Chapter 25

Optimization of a Bus and Rail Transit System with Feeder Bus Services under Different Market Regimes

Zhi-Chun Li, The Hong Kong Polytechnic University, Hong Kong and Huazhong University of Science and Technology, China; William H.K. Lam, The Hong Kong Polytechnic University, Hong Kong; S.C. Wong, The University of Hong Kong, Hong Kong

This paper proposes analytical models for optimizing a bus and rail transit system with feeder bus services under different market regimes. The market regimes concerned include: monopoly (with profit maximization), social optimum (with social welfare maximization), and oligopoly. In the proposed models, transit operator aims to optimize the frequencies and fares of the bus, rail and feeder bus services, while accounting for the responses from transit passengers (in terms of travel mode choice as well as demand elasticity) to the level of transit services and fares. A solution algorithm is developed to solve the proposed models. Numerical results show that a single implementation of the feeder bus service scheme may not be most cost-effective. A joint implementation of the feeder bus service scheme and other schemes, such as transfer coordination between transit modes and integrated fare scheme, can significantly improve the performance of the multimodal transit system in terms of total social welfare.

Chapter 26

Modelling Dynamic Generation of a Choice Set in Pedestrian Networks

Takamasa Iryo and Yasuo Asakura, Kobe University, Japan; Ryota Onishi, Hankyu Railway Company Limited, Japan; Chiharu Samma, JCB Company Limited, Japan

Considerable interest has been shown in models that predict the behaviour of travellers in pedestrian networks. The complexity of the pedestrian's behaviour poses problems in investigation of these models; this complexity can be attributed to the inability of travellers to generate a choice set of destinations prior to their travel due to the lack of information regarding pedestrian networks. This study aims to model the manner in which travellers generate a choice set of destinations while walking. The following two principles are applied for constructing the model: the expected utility maximisation principle and the node-based searching principle. Using these principles, it is shown that travellers try to generate a choice set as soon as possible and stop searching when the effort in expanding the choice set does not pay off to obtain higher utility of the entire tour. Further, it is shown that the rule of stopping is identical to the optimal stopping problem. The solution methodology and characteristics of the model are shown. Then, the node-based searching principle and the stopping rule are tested against empirical data.

Chapter 27

A Common Modeling Framework for Dynamic Traffic Assignment and Supply Chain Management Systems with Congestion Phenomena

Georgios Kalafatas and Srinivas Peeta, Purdue University, U.S.A.

This paper seeks to illustrate the ability of the graph theoretic cell transmission model (GT-CTM), previously developed by the authors, to address some dynamic supply chain management (SCM) problems with congestion phenomena using a simple graphical representation. It further shows the conceptual equivalence between SCM and dynamic traffic assignment (DTA) problems using the GT-CTM framework. Thereby, the GT-CTM provides a generalized modeling framework to address dynamic network problems with congestion phenomena.

Chapter 28

A Pedestrian Model Considering Anticipatory Behaviour for Capacity Evaluation

Miho Asano, National Institute for Land and Infrastructure Management, Japan; Takamasa Iryo, Kobe University, Japan; Masao Kuwahara, The University of Tokyo, Japan

This study proposes a microscopic model of a pedestrian flow that considers the anticipation and decision processes of pedestrians interacting with each other by incorporating game theory. Modelling pedestrian flow in crowded places is essential for evaluating pedestrian facilities and their capacity. It is necessary to consider the anticipation and decision processes of pedestrians interacting with each other because pedestrians are likely to collide frequently in congested situations. This study proposes a model that utilizes the concept of Nash equilibrium. An algorithm for simulating the model is proposed, along with an algorithm for determining the best route of a pedestrian considering the existence of other pedestrians. That the proposed model is capable of reproducing the congested pedestrian flow is confirmed by numerical tests.

Chapter 29

A Comparative Assessment of Stochastic Capacity Estimation Methods

Justin Geistefeldt, Hessian Road and Traffic Authority, Germany; Werner Brilon, Ruhr-University Bochum, Germany

The stochastic nature of highway capacity has gained increasing attention in recent times. For the empirical estimation of capacity distribution functions based on measured traffic data, two methodologies have received considerable application: The direct estimation of breakdown probabilities for groups of traffic volumes on the one hand and the estimation of capacity distribution functions based on statistical models for censored data on the other hand. The objective of the paper is to compare these methods in terms of estimation accuracy, applicability, and consistency of the results. The theoretical differences of both methods as well as the consequences for application are discussed and analyzed based on empirical traffic data as well as data from macroscopic simulation. The analysis yields that the capacity estimation based on models for censored data performs better than the direct breakdown probability estimation technique, particularly concerning the consistency of the estimated capacity distribution functions.

Chapter 30

Supply-demand Diagrams and a New Framework for Analyzing the Inhomogeneous Lighthill-Whitham-Richards Model

W.L. Jin, University of California, U.S.A.; L. Chen, University of Science and Technology of China, China; Elbridge Gerry Puckett, University of California, U.S.A.

Traditionally, the Lighthill-Whitham-Richards (LWR) models for homogeneous and inhomogeneous roads have been analyzed in flux-density space with the fundamental diagram of the flux-density relation. In this paper, we present a new framework for analyzing the LWR model, especially the Riemann problem at a linear boundary in which the upstream and downstream links are homogeneous and initially carry uniform traffic. We first review the definitions of local supply and demand functions and then introduce the so-called supply-demand diagram, on which a traffic state can be represented by its supply and demand, rather than as density and flux as on a fundamental diagram. It is well-known that the solutions to the Riemann problem at each link are self-similar with a stationary state, and that the wave on the link is determined by the stationary state and the initial state. In our new framework, there can also exist an interior state next to the linear boundary on each link, which takes infinitesimal space, and admissible conditions for the upstream and downstream stationary and interior states can be derived in supply-demand space. With an entropy condition consistent with a local supply-demand method in interior states, we show that the stationary states exist and are unique within the solution framework. We also develop a graphical scheme for solving the Riemann problem, and the results are shown to be consistent with those in the literature. We further discuss asymptotic stationary states on an inhomogeneous ring road with arbitrary initial conditions and demonstrate the existence of interior states with a numerical example. The framework developed in this study is simpler than existing ones and can be extended for analyzing the traffic dynamics in general road networks.

Chapter 31

Network Evaluation Based on Connectivity Vulnerability

Fumitaka Kurauchi, Gifu University, Japan; Nobuhiro Uno, Kyoto University, Japan; Agachai Sumalee, The Hong Kong Polytechnic University, Hong Kong; Yumiko Seto, Kyoto University, Japan

Network reliability indices are generally expressed as a multiplier of the probability that the specific event may occur and the consequence of the event. It means that an inaccurate estimation of the probability of event occurrence may lead to different evaluation of the reliability. In contrast, the concept of “network vulnerability” has been proposed for evaluating the network component only by the consequence of the degradation. Though the concept of vulnerability may have avoided the uncertainty of the capacity degradation, it still requires an exact measurement of the traffic demand in the network which may not be accurate especially in the case of the disaster. We thus propose the method of critical link identification from the topological point of view, i.e., connectivity vulnerability. The concept of the k -edge-connectivity is applied in this study. The number of distinct paths with acceptable travel time between each origin-destination (OD) pair is used to measure the connectivity of that OD pair (similar to the concept of k -edge connectivity). A mathematical program for identifying acceptable distinct paths between each OD pair is formulated. The proposed method and indicator of connectivity vulnerability is then tested with the Kansai road network.

Chapter 32

Reliability-based Dynamic Discrete Network Design with Stochastic Networks

Hao Li, Michiel C.J. Bliemer and Piet H.L. Bovy, Delft University of Technology, The Netherlands

Stochastic supply and fluctuating travel demand lead to stochastic travel times and travel costs for travelers. This paper will firstly focus on modeling of travelers' departure time/route choice behavior under stochastic capacities. By analytically proving the equivalency of the scheduling approach and the mean variance approach, a generalized travel cost function is derived to model travelers' departure time/route choice behavior under uncertainty. The proposed generalized travel cost function, which is more behaviorally sound and flexible, will be adopted to model a reliability-based long term user equilibrium with departure time choices. A reliability-based dynamic network design approach is proposed and formulated in which the numbers of lanes on all potential links are the design variables. A combined road network-oriented genetic algorithm and set evaluation algorithm is proposed to solve the dynamic network design problem. A new systematic approach is proposed to eliminate the infeasible, unrealistic and illogical lane designs in order to reduce the solution space and to save computation time. The proposed reliability-based dynamic network design approach is applied to a hypothetical network, and its solutions are compared to a corresponding static network design approach. It is concluded that the static network design approach may lead to poor designs. In general static traffic assignment underestimates the overall total network travel time and total network travel costs. The dynamic network design approach appears to result in a fairly good allocation of road capacity over space and makes the best utilization of the network capacity over time. A version of the Braess paradox appears in case of reliability-based cost functions in both static and dynamic networks.

Chapter 33

Flow Breakdown, Travel Reliability and Real-time Information in Route Choice Behavior

Jing Dong and Hani S. Mahmassani, Northwestern University, U.S.A.

The objective of this study is to provide travelers in a congested network with information on the relative reliability of alternative travel routes, in addition to the usual travel time information. Towards this end, we develop a travel reliability measure that captures the probability of flow breakdown along a given facility, along with the conditional expected delay associated with occurrence of breakdown. The paper develops a methodology for estimating the key elements of this measure, and provides an empirical realization using commonly available freeway sensor data. Both elements of the reliability measure, namely the probability of flow breakdown and the extra delay caused by breakdown are represented as functions of flow rate, and calibrated for each road section based on field data. The proposed travel reliability measure could therefore be obtained off-line by analyzing historical data and computed on-line when real-time measurements are available. The reliability measure is incorporated in the generalized cost function underlying drivers' route choice behavior, as a basis for dynamic traffic assignment under reliability information provision to users. An analytical illustration using an idealized two route network is provided, confirming that reliability information could improve system performance and increase overall social welfare. Application of the approach to the Irvine, CA test network provides a real-network assessment of the value of travel reliability information in the context of real-time traveler information provision. The experimental results show that reliability information helps to relieve congestion on the freeway, increase system utilization and reduce travelers' trip time.

Chapter 34

Optimal Sensor Placement for Freeway Travel Time Estimation

Xuegang (Jeff) Ban, Rensselaer Polytechnic Institute, U.S.A.; Ryan Herring, J.D. Margulici and Alexandre M. Bayen, University of California, U.S.A.

This article presents a modeling framework and a polynomial solution algorithm for determining optimal locations of point detectors used to compute freeway travel times. First, an objective function is introduced to minimize the deviation of estimated and actual travel times of all individual sub-segments of a freeway route. By discretizing the problem in both time and space, we formulate it as a dynamic programming model, which can be solved via a shortest path search in an acyclic graph. Numerical examples are provided to illustrate the model and algorithm using microscopic traffic simulation and GPS data from the *Mobile Century* experiment recently conducted by the University of California, Berkeley, Nokia and California Department of Transportation (Caltrans).

Chapter 35

Updating Dynamic Origin-destination Matrices using Observed Link Travel Speed by Probe Vehicles

Toshiyuki Yamamoto and Tomio Miwa, Nagoya University, Japan; Tomonori Takeshita, Shizuoka Prefecture, Japan; Takayuki Morikawa, Nagoya University, Japan

A method for updating dynamic O-D matrix using observed link travel speed of probe vehicles is developed. The method consists of two parts: link flow of total traffic is estimated from the link travel speed of probe vehicles, and dynamic O-D matrix is estimated using the estimated link flow and historical O-D matrix. The $k-v$ function derived from the acceleration model by Gazis et al. (1961) is applied to the link flow estimate, and the entropy maximization model proposed by Willumsen (1984) is applied to the dynamic O-D demand estimate. By using Bayesian inference approach, the variance of the estimate as well as the point estimate of link flow is obtained. Also, the entropy maximization model is extended to incorporate the difference in the reliability of link flow estimates among links. The results of a case study show that the accuracy of the estimated dynamic O-D matrix is improved by the proposed method, and that the accuracy of the link flow estimates obtained in dynamic O-D demand estimation is improved by the proposed method, too.