12. Network pricing optimization in multi-user and multimodal context with elastic demand

1. Bellei, G; Gentile, G; Papola, N
2. TRANSPORT RES B-METH

> Network Pricing Optimization (NPO) is formulated first as a Network Design Problem (NDP) where the design variables are tolls, the objective function is the Social Surplus and the equilibrium constraint is any current multi-user multimodal stochastic traffic assignment model with elastic demand up to trip generation and asymmetric arc cost function Jacobian. NPO is then formulated also as an Efficient Allocation Problem (EAP), where an optimal flow pattern, the System Optimum (SO), is sought and tolls are consistently determined. Necessary and sufficient conditions for the solutions to both problems are stated, showing the validity of the marginal pricing principle in the context considered.

13. A new general equilibrium model

1. Xiang, YL; Smith, MJ; Logie, M
2. APPL OPTIMIZAT

> In this paper we present a new general equilibrium model appropriate for multi-modal networks. A solution of the model gives the equilibrium distribution of travellers and vehicles over a transportation network. The model is expressed in terms of inverse cost-flow functions; and delays are explicitly modelled. The paper outlines an equilibration algorithm and convergence results for a small network are provided. The equilibrium model has been designed in such a way that optimisation procedures may naturally be added to the equilibration algorithm.

16. Parking capacity and pricing in park'n ride trips: A continuous equilibrium network design problem

1. Garcia, R; Marin, A
2. ANN OPER RES

> In this paper we consider the problem of designing parking facilities for park'n ride trips. We present a new continuous equilibrium network design problem to decide the capacity and fare of these parking lots at a tactical level. We assume that the parking facilities have already been located and other topological decisions have already been taken. The modeling approach proposed is mathematical programming with equilibrium constraints. In the outer optimization problem, a central Authority evaluates the performance of the transport network for each network design decision. In the inner problem a multimodal traffic assignment with combined modes, formulated as a variational inequality problem, generates the share demand for modes of transportation, and for parking facilities as a function of the design variables of the parking lots. The objective is to make optimal parking investment and pricing decisions in order to minimize the total travel cost in a subnetwork of the multimodal transportation system. We present a new development in model formulation based on the use of generalized parking link cost as a design variable. The bilevel model is solved by a simulated annealing algorithm applied to the continuous and non-negative design decision variables. Numerical tests are reported in order to illustrate the use of the model, and the ability of the approach to solve applications of moderate size.

22. A large scale stochastic multi-class schedule-based transit model with random coefficients - Implementation and algorithms

1. Nielsen, OA
2. OPER RES COMPUT SCI

> Public transport assignment models are increasing in complexity in order to describe passengers' route choices as detailed and correctly as possible. Important trends in the development are 1) schedule-based models, 2) inclusion of feeder modes, 3) use of stochastic components to describe differences in passengers' preferences within and between trip purposes and classes, as well as to describe non-explained variation within a utility theory framework, and 4) consideration of capacity problems at coach level, system level and terminal level. In the East Denmark Model, such a large-scale transit assignment model was developed and estimated within a Stochastic User Equilibrium framework solved by the Method of Successive Averages. The model covered a metropolitan area including its hinterland (2,000 lines, 50,000 runs, 300,000 stops, and 1 million nodes and 10 million arcs in the calculation graph). The paper outlines the experiences from this project, and the subsequent research and development using the case as 'modelling laboratory'. The main focus of the paper is to describe the estimation of the utility functions, and to discuss and suggest optimisation of the solution algorithm.

26. MULTI-LAYER NETWORK APPROACH FOR MODELING GENERAL COMBINED-MODE TRIPS

1. Wu, Z. X.; Ye, H. S.; Sun, M.; Lam, William H. K.
2. nan

> This paper describes a multi-layer approach for modeling general combined-mode trips. The model formulation is based on an extended network framework. termed a multi-layer network. Two major problems arising from the specification of a multi-modal network equilibrium model are addressed, i.e. route (or path) enumeration and travel choice in a network with multiple transport modes. It is shown that the multi-layer network approach can facilitate the generation of feasible routes in a multi-modal setting. A feasible route in the multi-layer network is characterized by a combined mode, which indicates the feature of the used modes or mode combinations along the route. All feasible routes between each origin-destination (OD) pair are grouped, according to the combined modes of routes, into four subsets: auto, transit, auto-transit, and pure walking. The travel choice model is given by a nested logit model where the upper level is focused on combined-mode choice while the lower level on route choice. The multi-modal network equilibrium problem is mathematically formulated as a variational inequality (VI) problem. In addition, interactions among various motorized modes sharing the same road space, as well as nonlinear transit fare structures are taken into account in the multi-modal network equilibrium problem.

27. Network equilibrium with combined modes: models and solution algorithms

1. Garcia, R; Marin, A
2. TRANSPORT RES B-METH

> In this paper we propose a new model for the equilibrium multi-modal assignment problem with combined modes (MAPCM) for the case of asymmetric costs. MAPCM is stated on a generic passenger assignment equilibrium model, on a generalized traffic assignment model, and on a nested logit distribution as demand model which explicitly takes into account the choice of mode of transport and

> transfer node among modal networks. This model is formulated as a variational inequality problem in the space of the hyperpath flows and then solved by the disaggregate simplicial decomposition (DSD) algorithm. Illustrations of the model and of the numerical approach are reported on two test networks with asymmetric cost functions. (C) 2004 Elsevier Ltd. All rights reserved.

29. Advanced pricing and rationing policies for large scale multimodal networks

1. Gentile, G; Papola, N; Persia, L
2. TRANSPORT RES A-POL

> The applying of simplified schemes, such as cordon pricing, as second-best solution to the toll network design problem is investigated here in the context of multiclass traffic assignment on multimodal networks. To this end a suitable equilibrium model has been developed, together with an efficient algorithm capable of simulating large scale networks in quite reasonable computer time. This model implements the theoretical framework proposed in a previous work on the toll optimization problem, where the validity of marginal cost pricing for the context at hand is stated. Application of the model to the real case of Rome shows us, not only that on multimodal networks a relevant share (up to 20%) of the maximum improvements in terms of social welfare achievable with marginal cost pricing can in fact be obtained through cordon pricing, but also that in practical terms rationing is a valid alternative to pricing, thus getting around some of the relevant questions (theoretical, technical, social) the latter raises. As a result we propose a practical method to analyze advanced pricing and rationing policies differentiated for user categories, which enables us to compare alternative operative solutions with an upper bound on social welfare based on a solid theoretical background. (c) 2005 Elsevier Ltd. All rights reserved.

33. A demand model with departure time choice for within-day dynamic traffic assignment

1. Bellei, Giuseppe; Gentile, Guido; Meschini, Lorenzo; Papola, Natale
2. EUR J OPER RES

> A within-clay dynamic demand model is formulated, embodying, in addition to the classic generation, distribution and modal split stages, an actual demand model taking into account departure time choice. The work focuses on this last stage, represented through an extension of the discrete choice framework to a continuous choice set. The dynamic multimodal supply and equilibrium model based on implicit path enumeration, which have been developed in previous work are outlined here, to define within-day dynamic elastic demand stochastic multimodal equilibrium as a fixed point problem on users flows and transit line frequencies. A MSA algorithm capable, in the case of Logit route choice models, of supplying equilibrium flows and frequencies on real dimension networks, is presented, as well as the specific procedures implementing the departure time choice and actual demand models. Finally, the results obtained on a test network are presented and conclusions are drawn. (c) 2005 Elsevier B.V. All rights reserved.

34. A study on network design problems for multi-modal networks by probit-based stochastic user equilibrium

1. Uchida, Kenetsu; Sumalee, Agachai; Watling, David; Connors, Richard
2. NETW SPAT ECON

> This paper develops a multi-modal transport network model considering various travel modes including railway, bus, auto, and walking. Travellers are assumed to choose their multi-modal routes so as to minimise their perceived disutilities of travel following the Probit Stochastic User Equilibrium (SUE) condition. Factors influencing the disutility of a multi-modal route include actual travel times, discomfort on transit systems, expected waiting times, fares, and constants specific to transport modes. The paper then deals with the multi-modal network design problem (NDP). The paper employs the method of sensitivity analysis to define linear approximation functions between the Probit SUE link flows and the design parameters, which are then used as constraints in the sub-problem of the NDP instead of the original SUE condition. Based on this reformulated NDP, an efficient algorithm for solving the problem is proposed in the paper. Two instances of this general NDP formulation are then presented in the paper: the optimal frequency design problem for public transport services (FDP), and the anti-freezing admixture dispersion problem (AADP).

35. Congestion pricing for multi-modal transportation systems

1. Hamdouch, Younes; Florian, Michael; Hearn, Donald W.; Lawphongpanich, Siriphong
2. TRANSPORT RES B-METH

> In this paper, we extend the toll pricing framework previously developed for vehicular traffic networks to ones with the potential to include many modes of transportation such as walking, driving, and using public conveyance (e.g., buses, subways, and trains). To determine tolls, we construct a user equilibrium and system optimal model. In both models, we assume that users adopt strategies or hyperpaths to travel between each origin-destination pair and the demand between each pair is fixed. However, the choice between driving and using public transportation is determined by a binomial logit function. As in the case of vehicular traffic networks, the set of valid tolls can be obtained from the solution to the system problem and the equilibrium conditions for the user problem. Then, secondary objective functions similar to those for traffic networks can be used to select a toll vector for, e.g., implementation. We provide a numerical example to illustrate our approach.

37. Transit competitiveness in polycentric metropolitan regions

1. Casello, Jeffrey M.
2. TRANSPORT RES A-POL

> This paper analyzes the potential to, and impacts of, increasing transit modal split in a polycentric metropolitan area the Philadelphia, Pennsylvania region. Potential transit riders are preselected as those travelers whose trips begin and end in areas with transit-supportive land uses, defined as activity centers, areas of high-density employment and trip attraction. A multimodal traffic assignment model is developed and solved to quantify the generalized cost of travel by transit services and private automobile under (user) equilibrium conditions. The model predicts transit modal split by identifying the origin-destination pairs for which transit offers lower generalized cost. For those origin-destination pairs for which transit does not offer the lowest generalized cost, I compute a transit competitiveness measure, the ratio of transit generalized cost to auto generalized cost. The model is first formulated and solved for existing transit service and regional pricing schemes. Next, various transit incentives (travel time or fare reductions, increased service) and auto disincentives (higher out of pocket expenses) are proposed and their impacts on individual travel choices and system performance are quantified. The results suggest that a coordinated policy of improved transit service and some auto

> disincentives is necessary to achieve greater modal split and improved system efficiency in the region. Further, the research finds that two levels of coordinated transit service, between and within activity centers, are necessary to realize the greatest improvements in system performance. (c) 2006 Elsevier Ltd. All rights reserved.

38. A Simulation-Based Dynamic Intermodal Network Equilibrium Algorithm

1. Chang, Elaine; Ziliaskopoulos, Athanasios
2. nan

> This paper introduces a Variational Inequality (VI) formulation for the time-dependent combined mode split and traffic assignment problem. Travel costs are represented by generalized cost functions and mode choices are deterministically obtained based on assignment to intermodal least cost paths without accounting for possible randomness in travelers' choices. The intermodal user equilibrium (IUE) is estimated using an inner approximation (IA) algorithm that results in a nonlinear program with linear constraints. The algorithm converges assuming continuous and monotonic path travel cost functions. The paths on multimodal networks are computed with an intermodal optimum path algorithm; a cell transmission-based simulator, enhanced to account for both automobile and transit vehicles, is used to estimate the path travel costs. A heuristic search approach is proposed and implemented in the VISTA simulation-based framework. Computational results are presented on example networks to test convergence and equilibrium.

40. A multiclass simultaneous transportation equilibrium model

1. Hasan, Mohamad K.; Dashti, Hussain M.
2. NETW SPAT ECON

> Single class travel forecasting models assume that all travelers are similar in their travel-decision characteristics, such as their money-value of the time and their sensitivity to travel times in choosing their origin, destination and mode of travel, etc. To obtain more realistic models, travelers are often divided into classes, either by socio-economic attributes (e.g., income level, car availability, etc.) or by the purpose (e.g., home-based-work, non-home-based-work, home-based-shopping, etc.) of their travel, assuming that travel-decision characteristics are the same within each class, but differ among classes. However, the development of this concept of multiple classes increases the mathematical complexity of travel forecasting models. All the existing multiclass combined models consider the trip generation step of transportation planning process is exogenous to the combined prediction process. In this paper we enhance the Simultaneous Transportation Equilibrium Model (STEM) that developed by Safwat and Magnanti in 1988, and explicitly combined trip generation step, to be a multiclass model in terms of socio-economic group, trip purpose, pure and combined transportation modes, as well as departure time, all interacting over a physically unique multimodal network. The developed Multiclass Simultaneous Transportation Equilibrium Model (MSTEM) is formulated as a Variational Inequality problem and a diagonalization algorithm is proposed to solve it.

41. The bicriterion multimodal assignment problem: Introduction, analysis, and experimental results

1. Pedersen, Christian Roed; Nielsen, Lars Relund; Andersen, Kim Allan
2. INFORMS J COMPUT

> We consider the bicriterion multimodal assignment problem, which is a new generalization of the classical linear assignment problem. A two-phase solution method using an effective ranking scheme is presented. The algorithm is valid for generating all nondominated criterion points or an approximation. Extensive computational results are conducted on a large library of test instances to test the performance of the algorithm and to identify hard test instances. Also, test results of the algorithm applied to the bicriterion assignment problem are provided.

42. Multimodal, multiclass stochastic dynamic traffic assignment for evaluating information provision strategies

1. Lee, Seungiae
2. J ADV TRANSPORT

> A multimodal, multiclass stochastic dynamic traffic assignment model was developed to evaluate pre-trip and enroute travel information provision strategies. Three different information strategies were examined: user optimum [UO], system optimum [SO] and mixed optimum [MO]. These information provision strategies were analyzed based on the levels of traffic congestion and market penetration rate for the information equipment. Only two modes, bus and car, were used for evaluating and calculating the modal split ratio. Several scenarios were analyzed using day-to-day and within day dynamic models. From the results analyzed, it was found that when a traffic manager provides information for drivers using the UO strategy and drivers follow the provided information absolutely, the total travel time may increases over the case with no information. Such worsening occurs when drivers switch their routes and face traffic congestion on the alternative route. This phenomenon is the 'Braess Paradox'.

43. Dynamic micro-assignment modeling approach for integrated multimodal urban corridor management

1. Zhou, Xuesong; Mahmassani, Hani S.; Zhang, Kuilin
2. TRANSPORT RES C-EMER

> Development and analysis of demand management strategies for integrated multimodal urban corridor management requires application of a new generation of demand modeling and network analysis tools. This paper describes the development of a dynamic trip micro-assignment and (meso) simulation system that incorporates individual tripmaker choices of travel mode, departure time and route in multimodal urban transportation networks (with different travel modes such as drive alone, shared ride, bus rapid transit and metro rail). These travel choice dimensions arc integrated in a stochastic utility maximization framework that considers multiple user decision criteria such as travel time, travel cost, schedule delay, as well as travel time reliability. A variational inequality model is first proposed to describe the general stochastic dynamic traffic user equilibrium problem. For a typical case that assumes the logit-based alternative choice model, this paper develops an equivalent gap function-based optimization formulation and a heuristic iterative solution procedure. Based on a multidimensional network representation, an efficient time-dependent least cost path algorithm is embedded to generate an intermodal route choice set that recognizes time-dependent mode transfer costs and feasible mode transfer sequences. A two-stage estimation procedure that can systematically utilize historical static demand information, time-dependent link counts, as well as empirically calibrated stochastic departure time choice models is proposed to infer commuters' preferred arrival time distribution, which is important in modeling departure time choice dynamics. A case study based

> on a large-scale multimodal transportation network (adapted from the Baltimore-Washington corridor) is presented to illustrate the capabilities of the methodology and provide insight into the potential benefit of integrated multimodal corridor management. (C) 2007 Published by Elsevier Ltd.

44. Markovian traffic equilibrium

1. Baillon, J. -B.; Cominetti, R.
2. MATH PROGRAM

> We analyze an equilibrium model for traffic networks based on stochastic dynamic programming. In this model passengers move towards their destinations by a sequential process of arc selection based on a discrete choice model at every intermediate node in their trip. Route selection is the outcome of this sequential process while network flows correspond to the invariant measures of the underlying Markov chains. The approach may handle different discrete choice models at every node, including the possibility of mixing deterministic and stochastic distribution rules. It can also be used over a multi-modal network in order to model the simultaneous selection of mode and route, as well as to treat the case of elastic demands. We establish the existence of a unique equilibrium, which is characterized as the solution of an unconstrained strictly convex minimization problem of low dimension. We report some numerical experiences comparing the performance of the method of successive averages (MSA) and Newton's method on one small and one large network, providing a formal convergence proof for MSA.

52. COMBINED MODAL SPLIT AND ASSIGNMENT MODEL FOR THE MULTIMODAL TRANSPORTATION NETWORK OF THE ECONOMIC CIRCLE IN CHINA

1. Li, Shuang; Deng, Wei; Lv, Yisheng
2. TRANSPORT-VILNIUS

> Economic circles have been formed and developing in China. An economic circle consists of more than one closely adjoining central cities and their influence zones. It is always the major engine for the development of one country's economy and even for the world economy. A combined modal split and assignment model with deterministic travel demand is proposed for modelling passengers' choices of intercity bus and train which are two main competing modes in the multimodal transportation network of the economic circle. The generalized travel cost model of highway and railway are used incorporating travel time, ticket fare and passenger's discomfort. On the highway network, the interactions of private vehicles and intercity buses are asymmetric. Thus, a variational inequality formulation is proposed to describe the combined model. The streamlined diagonalization algorithm is presented to solve the combined model. The multimodal transportation network based on Yangtze River Delta economic circle is presented to illustrate the proposed method. The results show the efficiency of the proposed model.

57. An activity-based approach for scheduling multimodal transit services

1. Li, Zhi-Chun; Lam, William H. K.; Wong, S. C.; Sumalee, A.
2. TRANSPORTATION

> This paper proposes a new activity-based transit assignment model for investigating the scheduling (or timetabling) problem of transit services in multi-modal transit networks. The proposed model can be used to generate the short-term and long-term timetables of multimodal transit lines for transit

> operations and service planning purposes. The interaction between transit timetables and passenger activity-travel scheduling behaviors is captured by the proposed model, as the activity and travel choices of transit passengers are considered explicitly in terms of departure time choice, activity/trip chain choices, activity duration choice, transit line and mode choices. A heuristic solution algorithm which combines the Hooke-Jeeves method and an iterative supply-demand equilibrium approach is developed to solve the proposed model. Two numerical examples are presented to illustrate the differences between the activity-based approach and the traditional trip-based method, together with comparison on the effects of optimal timetables with even and uneven headways. It is shown that the passenger travel scheduling pattern derived from the activity-based approach is significantly different from that obtained by the trip-based method, and that a demand-sensitive (with uneven headway) timetable is more efficient than an even-headway timetable.

61. Congestion Pricing for Schedule-Based Transit Networks

1. Hamdouch, Younes; Lawphongpanich, Siriphong
2. TRANSPORT SCI

> In this paper, we develop models for adjusting or setting fares on a transit system to encourage passengers to choose travel strategies that lead to the least travel delay for the entire system. In our problem setting, these fares vary with time of day. Similar to the one used to reduce congestion on vehicular traffic networks, our goal is to adjust or set fares so that a user equilibrium solution under the new fares yields the least delay or is system optimal. On the other hand, pricing frameworks for traffic networks such as marginal cost pricing do not readily apply because the travel delay in transit systems involves factors different from those in vehicular traffic and cannot be expressed in closed functional forms. The models herein are schedule based and account for loading priorities and individual vehicle capacities explicitly. Differences among the proposed models are illustrated with a small network.

62. Routing Traffic at Hub Facilities

1. O'Kelly, Morton E.
2. NETW SPAT ECON

> Flows arriving at a hub or a transshipment facility may need to be switched from one path to another to complete their journey. These transfer aspects of hub and spoke systems are widely recognized as a hindrance to efficient completion of transit trips. For example, time-consuming delays at transfer points for bus passengers are a major reason for poor levels of service between some nodes when the origin and destination are on different network lines. Such transfers also arise in multimodal interaction systems. This paper outlines a simple notation and analytical framework for optimizing flows within a hub (i.e. at nodes with transfers) and discusses several variants of the problem. This paper addresses prototype models for the efficient allocation of resources to facilitate the operation of interactions at the hub. The paper is primarily a conceptual and methodological overview, but well-recognized existing optimization models are suggested as being useful for some of the related tasks. Small numerical examples are used to illustrate some of the ideas.

63. Integrated Network Capacity Expansion and Traffic Signal Optimization Problem: Robust Bi-level Dynamic Formulation

1. Karoonsoontawong, Ampol; Waller, Steven Travis
2. NETW SPAT ECON

> This paper presents a robust optimization formulation, with an exact solution method, that simultaneously solves continuous network capacity expansion, traffic signal optimization and dynamic traffic assignment when explicitly accounting for an appropriate robustness measure, the inherent bi-level nature of the problem and long-term O-D demand uncertainty. The adopted robustness measure is the weighted sum of expected total system travel time (TSTT) and squared up-side deviation from a fixed target. The model propagates traffic according to Daganzo's cell transmission model. Furthermore, we formulate five additional, related models. We find that when evaluated in terms of robustness, the integrated robust model performs the best, and interestingly the sequential robust approach yields a worse solution compared to certain sequential and integrated approaches. Although the adopted objective of the integrated robust model does not directly optimize the variance of TSTT, our experimental results show that the robust solutions also yield the least-variance solutions.

64. A biased random-key genetic algorithm for road congestion minimization

1. Buriol, Luciana S.; Hirsch, Michael J.; Pardalos, Panos M.; Querido, Tania; Resende, Mauricio G. C.; Ritt, Marcus
2. OPTIM LETT

> One of the main goals in transportation planning is to achieve solutions for two classical problems, the traffic assignment and toll pricing problems. The traffic assignment problem aims to minimize total travel delay among all travelers. Based on data derived from the first problem, the toll pricing problem determines the set of tolls and corresponding tariffs that would collectively benefit all travelers and would lead to a user equilibrium solution. Obtaining high-quality solutions for this framework is a challenge for large networks. In this paper, we propose an approach to solve the two problems jointly, making use of a biased random-key genetic algorithm for the optimization of transportation network performance by strategically allocating tolls on some of the links of the road network. Since a transportation network may have thousands of intersections and hundreds of road segments, our algorithm takes advantage of mechanisms for speeding up shortest-path algorithms.

65. Robust congestion pricing under boundedly rational user equilibrium

1. Lou, Yingyan; Yin, Yafeng; Lawphongpanich, Siriphong
2. TRANSPORT RES B-METH

> This paper investigates congestion pricing strategies in static networks with boundedly rational route choice behavior. Under such behavior, users do not necessarily choose a shortest or cheapest route when doing so does not reduce their travel times by a significant amount. A general path-based definition and a more restrictive link-based representation of boundedly rational user equilibrium (BRUE) are presented. The set of BRUE flow distributions is generally non-convex and non-empty. The problems of finding best- and worst-case BRUE flow distributions are formulated and solved as mathematical programs with complementarity constraints. Because alternative tolled BRUE flow distributions exist, our congestion pricing models seek a toll vector or pattern that minimizes the system travel time of the worst-case tolled BRUE flow distribution. As formulated. the models are generalized semi-infinite min-max problems and we propose a heuristic algorithm based on penalization and a cutting-plane scheme to solve them. Numerical examples arc presented to illustrate key concepts and results.

66. Stochastic multi-modal transport network under demand uncertainties and adverse weather condition

1. Sumalee, Agachai; Uchida, Kenetsu; Lam, William H. K.
2. TRANSPORT RES C-EMER

> This paper proposes a multi-modal transport network assignment model considering uncertainties in both demand and supply sides of the network. These uncertainties are due to adverse weather conditions with different degrees of impacts on different modes. The paper provides the derivations of mean and variance-covariance of the stochastic passenger flows and dis-utility terms involved in the route/mode choice model under the common-line framework. The risk-averse travelers are assumed to consider both the mean and variance of the random perceived travel time on each multi-modal path in their path choice decisions. The model also considers travelers' perception errors by using a Probit stochastic user equilibrium framework which is formulated as fixed point problem. A heuristic solution algorithm is proposed to solve the fixed point problem. Numerical examples are presented to illustrate the applications of the proposed model.

69. Urban university campus transportation and parking planning through a dynamic traffic simulation and assignment approach

1. Bustillos, Brenda I.; Shelton, Jeffrey; Chiu, Yi-Chang
2. TRANSPORT PLAN TECHN

> Many urban university campuses are considered major trip attractors. Considering the multimodal and complex nature of university campus transportation planning and operation, this paper proposes a dynamic traffic simulation and assignment analysis approach and demonstrates how such a methodology can be successfully applied. Central to the research is the estimation of trip origin-destinations and the calibration of a parking lot choice model. Dynamic simulation is utilized to simulate multiple modes of transportation within the transportation network while further assigning these modes with respect to various mode-specific roadway accessibilities. A multiple vehicle-class simulation analysis for planning purposes becomes a critical capability to predict how faculty and staff who once parked within the campus core choose other nearby alternate parking lots. The results highlight the effectiveness of the proposed approach in providing integrated and reliable solutions for challenging questions that face urban university campus planners and local transportation jurisdictions.

72. EXTENDED GREAT DELUGE APPROACH FOR THE INTEGRATED DYNAMIC BERTH ALLOCATION AND CRANE ASSIGNMENT PROBLEM

1. El Asli, Neila; Thien-My Dao; Abou, Seraphin
2. nan

> Globalization has quickly increased the volume of commodity flows using all modes of transport. Specifically, since the 1970s, containerization has increasingly facilitated the transport of goods throughout the world, and every major port is expected to double, and possibly triple, its container traffic by 2020. In order to accommodate the growth in international container transport, terminals must make significant changes to keep pace with increasing demand. One important manner in which existing terminal capacity could be increased would be through an increase in their efficiency. In this paper, we consider terminal efficiency from the perspective of simultaneously improving both berth and quay crane scheduling. The approach is applied to a modeling scheme found in the literature, and

> this study contributes to knowledge by improving the results found using a new metaheuristic and a crane transfer refinement procedure.

74. Optimal selection of build-operate-transfer projects on transportation networks

1. Wu, Di; Yin, Yafeng; Lawphongpanich, Siriphong
2. TRANSPORT RES B-METH

> This paper considers the problem of how to select highway projects for the build-operate-transfer (BOT) development with the objective of improving the social benefit while ensuring the marketability of those selected. The problem can be viewed as a tri-level leader-follower game and is formulated as a mixed integer program with equilibrium constraints. Without solving the associated problem, we show that optimal tolls and travel times on selected BOT highways can be determined from their attributes under mild assumptions. This leads to an efficient heuristic algorithm for solving the project selection problem. (C) 2011 Elsevier Ltd. All rights reserved.

77. Impact analysis of cordon-based congestion pricing on mode-split for a bimodal transportation network

1. Meng, Qiang; Liu, Zhiyuan
2. TRANSPORT RES C-EMER

> This paper investigates the impact of cordon-based congestion pricing scheme on the mode-split of a bimodal transportation network with auto and rail travel modes. For any given toll-charge pattern, its impact on the mode-split can be estimated by solving a combined mode-split and traffic-assignment problem. Using a binary logit model for the mode-split, the combined problem is converted into a traffic-assignment problem with elastic demand. Probit-based stochastic user equilibrium (SUE) principle is adopted for this traffic-assignment problem, and a continuously distributed value of time (VOT) is assumed to convert the toll charges and transit fares into time-units. This combined mode-split and traffic-assignment problem is then formulated as a fixed-point model, which can be solved by a convergent Cost Averaging method. The combined mode-split and traffic-assignment problem is then used to analyze a multimodal toll design problem for cordon-based congestion pricing scheme, with the aim of increasing the mode-share of public transport system to a targeted level. Taking the fixed-point model as a constraint, the multimodal toll design problem is thus formulated as a mathematical programming with equilibrium constraints (MPEC) model. A genetic algorithm (GA) is employed to solve this MPEC model, which is then numerical validated by a network example. (C) 2011 Elsevier Ltd. All rights reserved.

78. Hierarchical network-based equilibrium model and algorithm for a mixed-traffic urban transport system

1. Si, Bingfeng; Zhong, Ming; Gao, Liang; Gao, Ziyou
2. TRANSPORT PLAN TECHN

> Many equilibrium models and algorithms based on homogeneous motorized traffic have been devised to model urban transport systems in developed countries, but they are inadequate when it comes to represent mixed-traffic urban transport systems, including automobiles, transit, bicycles, and pedestrians, in developing countries such as China or India. In these cases, traffic flow on a road segment is an aggregated result of travellers' combined mode/route choices and corresponding

> interactions. Therefore, a special assignment model and algorithm are needed for modeling these distinct behaviors. In this article, the structure of a mixed-traffic urban transport system is analyzed and then expanded and represented using a hierarchical network model based on graph theory. Based on the analysis of travelers' combined mode/route choices, generalized travel cost functions and link impedance functions for different modes are formulated, where the interferences between different modes on the same road segments are taken into account. Due to the 'asymmetric' nature of these functions, a variational inequality model is proposed to represent the equilibrium assignment problem in a mixed-traffic urban transport system. The corresponding solution algorithm is also presented. Finally, a numerical example is provided to illustrate the practicality of the proposed model and algorithm.

85. A reliability-based traffic assignment model for multi-modal transport network under demand uncertainty

1. Fu, Xiao; Lam, William H. K.; Chen, Bi Yu
2. J ADV TRANSPORT

> In densely populated and congested urban areas, the travel times in congested multi-modal transport networks are generally varied and stochastic in practice. These stochastic travel times may be raised from day-to-day demand fluctuations and would affect travelers' route and mode choice behaviors according to their different expectations of on-time arrival. In view of these, this paper presents a reliability-based user equilibrium traffic assignment model for congested multi-modal transport networks under demand uncertainty. The stochastic bus frequency due to the unstable travel time of bus route is explicitly considered. By the proposed model, travelers' route and mode choice behaviors are intensively explored. In addition, a stochastic state-augmented multi-modal transport network is adopted in this paper to effectively model probable transfers and non-linear fare structures. A numerical example is given to illustrate the merits of the proposed model. Copyright (c) 2012 John Wiley & Sons, Ltd.

86. Modelling impacts of adverse weather conditions on activity-travel pattern scheduling in multi-modal transit networks

1. Fu, Xiao; Lam, William H. K.; Meng, Qiang
2. TRANSPORTMETRICA B

> In general, adverse weather has significant influence on individuals' activity/travel choice behaviour and such influence is obviously greater in cities which suffer frequent rainy periods. Thus, the impacts of weather conditions should be taken into account in long-term transit service planning. In this paper, an activity-based network equilibrium model for scheduling daily activity-travel patterns (DATPs) in multi-modal transit networks under adverse weather conditions (with different rainfall intensities) is developed. The interdependency of individuals' activity/travel choices and weather conditions are comprehensively investigated. In the proposed model, the DATP choice problem under adverse weather conditions is transformed into an equivalent static transit assignment problem by constructing a novel super-network platform. A rule-based algorithm is proposed to automatically generate the super-network taking into account the rain effects implicitly. The effects of adverse weather on different transit modes and different activities are explicitly modelled. An efficient solution algorithm without prior enumeration of DATPs is proposed for solving the DATP scheduling problem in multi-

> modal transit networks. Numerical examples are presented to illustrate application of the proposed model and the solution algorithm.

87. A network equilibrium approach for modelling activity-travel pattern scheduling problems in multi-modal transit networks with uncertainty

1. Fu, Xiao; Lam, William H. K.
2. TRANSPORTATION

> An understanding of the interaction between individuals' activities and travel choice behaviour plays an important role in long-term transit service planning. In this paper, an activity-based network equilibrium model for scheduling daily activity-travel patterns (DATPs) in multi-modal transit networks under uncertainty is presented. In the proposed model, the DATP choice problem is transformed into a static traffic assignment problem by constructing a new super-network platform. With the use of the new super-network platform, individuals' activity and travel choices such as time and space coordination, activity location, activity sequence and duration, and route/mode choices, can be simultaneously considered. In order to capture the stochastic characteristics of different activities, activity utilities are assumed in this study to be time-dependent and stochastic in relation to the activity types. A concept of DATP budget utility is proposed for modelling the uncertainty of activity utility. An efficient solution algorithm without prior enumeration of DATPs is developed for solving the DATP scheduling problem in multi-modal transit networks. Numerical examples are used to illustrate the application of the proposed model and the solution algorithm.

88. Dynamic assignment with user information in multimodal networks

1. Atmani, Dihya; Lebacque, Jean-Patrick; Bhouri, Neila; Haj-Salem, Habib
2. TRANSP RES PROC

> The dynamic assignment of users has been widely studied for the road network while it is less considered for multimodal networks. In this article, we investigate the dynamic assignment of users in multimodal transportation systems while differentiating between informed and uninformed users. The problem is modeled as a multiagent system where we consider all of the modes that share the road infrastructure (private vehicles, taxis, buses, tramway, electric car sharing services), thus the users and vehicles of each mode are represented by an agent. As mentioned in the above, we consider two types of users: informed and uninformed. Our objective is to assess the impact of the presence of informed users on the dynamic assignment on the network. To do so, we provide an analytical study on the Braess paradox where we explore the possibility of improving the assignment of users through the information that is provided to them. The simulation model is cellular automata based and was executed on a multilevel network that includes a Braess paradox in order to validate the analytical results.

89. Merging transit schedule information with a planning network to perform dynamic multimodal assignment: lessons from a case study of the Greater Toronto and Hamilton Area

1. Weiss, Adam; Mahmoud, Mohamed S.; Kucirek, Peter; Habib, Khandker Nurul
2. CAN J CIVIL ENG

> Traffic assignment has traditionally been performed using aggregate static user equilibrium approaches for a single mode. These approaches are typically favoured over more complex dynamic multimodal

> micro and meso-simulated models. Investigations into dynamic multimodal assignment models have shown promise, prompting interest in the adoption of complex modelling structures. The development and operation of these complex models can still be problematic, highlighting the need for efficient approaches to allow practitioners to acquire and apply these models. This paper presents a method to modify existing static auto assignment networks for dynamic multimodal assignment. To complement this, a method, which improves the overall performance of the transit routing procedure used within many assignment models, is presented. These methods were tested using data from the Greater Toronto and Hamilton Area, and result in an assignment procedure with reasonable run time and results, suggesting potential for wide spread adoption of these approaches.

90. A SIMULATION-BASED DYNAMIC TRAFFIC ASSIGNMENT MODEL WITH COMBINED MODES

1. Meng, Meng; Shao, Chunfu; Zeng, Jingjing; Dong, Chunjiao
2. PROMET-ZAGREB

> This paper presents a dynamic traffic assignment (DTA) model for urban multi-modal transportation network by constructing a mesoscopic simulation model. Several traffic means such as private car, subway, bus and bicycle are considered in the network. The mesoscopic simulator consists of a mesoscopic supply simulator based on MesoTS model and a time-dependent demand simulator. The mode choice is simultaneously considered with the route choice based on the improved C-Logit model. The traffic assignment procedure is implemented by a time-dependent shortest path (TDSP) algorithm in which travellers choose their modes and routes based on a range of choice criteria. The model is particularly suited for appraising a variety of transportation management measures, especially for the application of Intelligent Transport Systems (ITS). Five example cases including OD demand level, bus frequency, parking fee, information supply and car ownership rate are designed to test the proposed simulation model through a medium-scale case study in Beijing Chaoyang District in China. Computational results illustrate excellent performance and the application of the model to analysis of urban multi-modal transportation networks.

91. Designing a multimodal feeder network by covering stops with different modes

1. Tahoorinia, Mohammad Mahdi; Mohaymany, Afshin Shariat; Gholami, Ali
2. CAN J CIVIL ENG

> Mass rapid transit requires a high demand to function economically. It is necessary to provide complementary services, such as buses and vans, to increase the required demand. This results in the possibility of providing high performance transit to a wider area. One of the suggested methods is to establish an integrated system of a feeder network. Using such systems provide not only sufficient demand for the main networks but also the possibility of an integrated public transportation system that extends to the entire city. In this paper, we have proposed a method for designing feeder networks that gives multimodal services at each stop simultaneously by assigning the demand to different modes. The demand assignment is based on optimum use of fleet rather than desirability functions. The objective is to minimize the costs of the users, operators, and society. Furthermore, as multimodal network designing is a complex problem, a metaheuristic approach, ant colony optimization, is used. For illustrating and comparing the results, a real example in Mashhad, Iran, is run through 16 different scenarios. The scenarios were designed with different unit costs, and the results

> have been compared with the latest study. In all of the scenarios, the network costs are lower than those in other methods.

92. Bus-based park-and-ride system: a stochastic model on multimodal network with congestion pricing schemes

1. Liu, Zhiyuan; Meng, Qiang
2. INT J SYST SCI

> This paper focuses on modelling the network flow equilibrium problem on a multimodal transport network with bus-based park-and-ride (P&R) system and congestion pricing charges. The multimodal network has three travel modes: auto mode, transit mode and P&R mode. A continuously distributed value-of-time is assumed to convert toll charges and transit fares to time unit, and the users' route choice behaviour is assumed to follow the probit-based stochastic user equilibrium principle with elastic demand. These two assumptions have caused randomness to the users' generalised travel times on the multimodal network. A comprehensive network framework is first defined for the flow equilibrium problem with consideration of interactions between auto flows and transit (bus) flows. Then, a fixed-point model with unique solution is proposed for the equilibrium flows, which can be solved by a convergent cost averaging method. Finally, the proposed methodology is tested by a network example.

102. Activity-based market equilibrium for capacitated multimodal transport systems

1. Chow, Joseph Y. J.; Djavadian, Shadi
2. TRANSP RES PROC

> Empirical studies have shown that demand for multimodal transport systems is highly correlated with activity schedules of individuals. Nonetheless, existing analytical equilibrium models of multimodal systems have only considered trip-based demand. We propose a new market equilibrium model that is sensitive to traveler activity schedules and system capacities. The model is based on a constrained mixed logit model of activity schedule choice, where each schedule in the choice set is generated with a multimodal extension of the Household Activity Pattern Problem. The extension explicitly accounts for both passenger choices of activity participation and multimodal choices like public transit, walking, and vehicle parking. The market equilibrium is achieved with Lagrangian relaxation to determine the optimal dual price of the capacity constraint, and a method of successive averages with column generation finds an efficient choice set of activity schedules to assign flows over the dynamic network load capacities. An example illustrates the model and algorithm, effects similar to Vickrey's morning commute model can be observed as a special case. A case study of the Oakville Go Transit station access last mile problem in the Greater Toronto Area is conducted with 166 survey samples reflecting 3,680 individuals. Results suggest that a $10 fixed parking fee at Oakville station would lead to a reduction of access auto share from 54.8% to 49.5%, an increase in access transit share from 20.7% to 25.9%, and a disutility increase of 11% for the of single-activity residents of Oakville. (C) 2015 The Authors. Published by Elsevier B.V.

103. Activity-based market equilibrium for capacitated multimodal transport systems

1. Chow, Joseph Y. J.; Djavadian, Shadi
2. TRANSPORT RES C-EMER

> Empirical studies have shown that demand for multimodal transport systems is highly correlated with activity schedules of individuals. Nonetheless, existing analytical equilibrium models of multimodal systems have only considered trip-based demand. We propose a new market equilibrium model that is sensitive to traveler activity schedules and system capacities. The model is based on a constrained mixed logit model of activity schedule choice, where each schedule in the choice set is generated with a multimodal extension of the household activity pattern problem. The extension explicitly accounts for both passenger choices of activity participation and multimodal choices like public transit, walking, and vehicle parking. The market equilibrium is achieved with Lagrangian relaxation to determine the optimal dual price of the capacity constraint, and a method of successive averages with column generation finds an efficient choice set of activity schedules to assign flows over the dynamic network load capacities. An example illustrates the model and algorithm, effects similar to Vickrey's morning commute model can be observed as a special case. A case study of the Oakville Go Transit station access last mile problem in the Greater Toronto Area is conducted with 166 survey samples reflecting 3680 individuals. Results suggest that a $10 fixed parking fee at Oakville station would lead to a reduction of access auto share from 54.8% to 49.5%, an increase in access transit share from 20.7% to 25.9%, and a disutility increase of 11% for the of single-activity residents of Oakville. (C) 2015 Elsevier Ltd. All rights reserved.

104. A bi-level programming for bus lane network design

1. Yu Bin; Kong Lu; Sun Yao; Yao Baozhen; Gao Ziyou
2. TRANSPORT RES C-EMER

> This paper proposes a bi-level programming model to solve the design problem for bus lane distribution in multi-modal transport networks. The upper level model aims at minimizing the average travel time of travelers, as well as minimizing the difference of passengers' comfort among all the bus lines by optimizing bus frequencies. The lower level model is a multi-modal transport network equilibrium model for the joint modal split/traffic assignment problem. The column generation algorithm, the branch-and-bound algorithm and the method of successive averages are comprehensively applied in this paper for the solution of the bi-level model. A simple numerical test and an empirical test based on Dalian economic zone are employed to validate the proposed model. The results show that the bi-level model performs well with regard to the objective of reducing travel time costs for all travelers and balancing transit service level among all bus lines. (C) 2015 Elsevier Ltd. All rights reserved.

109. Sensitivity Analysis of Welfare, Equity, and Acceptability Level of Transport Policies

1. Connors, R.; Patriksson, M.; Rydergren, C.; Sumalee, A.; Watling, D.
2. SPRINGER P MATH STAT

> Transport planners face a major challenge to devise policies to meet multiple expectations and objectives. While we know that transport networks are complex, multi-modal, and spatially distributed systems, there is now a long history of mathematical tools which assist planners in understanding travel movements. However, the objectives that they are asked to achieve do not always admit such a quantification, and so there is a potential mismatch between seemingly qualitatively driven objectives and quantitatively expressed models of the transport system. In the present chapter we address this mismatch, by focusing on three objectives that we believe represent the typical interests of a planner. These are namely: is the policy economically justifiable (efficient), is it fair (equitable), and is it

> justifiable to a democratic society (acceptable)? We provide mathematical representations of these three objectives and link them to mathematical theory of transport networks, in which we may explore the sensitivity of travel behaviour (and hence the objectives) to various multi-modal transport policies. The detailed steps for representing the policy objectives and sensitivities in the network are set out, and the results of a case study reported in which road tolls, road capacities, and bus fares are the policy variables. Overall, the chapter sets out a systematic method for planners to choose between multi-modal policies based on these three objectives.

112. Path-differentiated pricing in congestion mitigation

1. Zangui, Mahmood; Aashtiani, Hedayat Z.; Lawphongpanich, Siriphong; Yin, Yafeng
2. TRANSPORT RES B-METH

> Instead of charging tolls on individual links, this paper considers doing the same on paths. Path and link tolls are valid if they encourage motorists to use routes that collectively lead to a target distribution, e.g., one that minimizes travel delay. Because the numbers of valid link and path tolls are typically infinite, an objective in pricing tolls is to find a set of valid tolls that yields the least revenue to lessen the financial burden on motorists. Path tolls are generally more flexible than link tolls and this paper shows that this flexibility can substantially reduce the financial burden on motorists. Additionally, valid path tolls yielding the least revenue possess characteristics with interesting policy implications. To determine these path tolls, it is natural to formulate the problem as a mathematical program with complementarity constraints. However, this paper also investigates alternative formulations that highlight the problem's complexity and suggest ways to solve the problem efficiently.

117. Gap-based transit assignment algorithm with vehicle capacity constraints: Simulation-based implementation and large-scale application

1. Verbas, Omer; Mahmassani, Hani S.; Hyland, Michael F.
2. TRANSPORT RES B-METH

> This paper presents a gap-based solution method for the time-dependent transit assignment problem with vehicle capacity constraints. A two-level, simulation-based methodology is proposed, which finds the least cost hyperpaths at the upper level and performs the assignment of transit travelers on the hyperpaths at the lower level. The detailed simulation of travelers and vehicles at the lower level allows modelers to capture transit network complexities such as transfers/missed connections, receiving a seat/standing and boarding/being rejected to board. This 'hard' implementation of vehicle capacity constraints at the lower level is aggregated into 'soft constraints' at the upper level for the least cost hyperpath calculation. Using a gap-based assignment procedure, user equilibrium is reached on large-scale networks in a computationally efficient manner. The algorithm is tested on the large-scale Chicago Transit Authority network. The gap-based approach outperforms the commonly used method of successive averages approach in terms of rate of convergence and quality of results. Furthermore, sensitivity analyses with respect to network parameters illustrate the robustness of the proposed two-level solution procedure.

118. A path-based greedy algorithm for multi-objective transit routes design with elastic demand

1. Zarrinmehr, Amirali; Saffarzadeh, Mahmoud; Seyedabrishami, Seyedehsan; Nie, Yu Marco

2. PUBLIC TRANSPORT

> This paper is concerned with the problem of finding optimal sub-routes from a set of predefined candidate transit routes with the objectives of maximizing transit ridership as well as minimizing operational costs. The main contributions of this paper are: (1) considering transit ridership maximization in a multi-objective bi-level optimization framework; (2) proposing a greedy algorithm for the multi-objective design problem; (3) applying an efficient path-based algorithm to solve the lower level multi-modal traffic assignment problem. Numerical experiments indicate that the proposed algorithm is not only able to approximate the Pareto-optimal solutions with satisfactory accuracy, but also achieves a fast performance even for problems of real-world scale.

121. A simulation-based multiclass, multimodal traffic assignment model with departure time for evaluating traffic control plans of planned special events

1. Lin, Yun-Zhu; Chen, Wei-Hao
2. TRANSP RES PROC

> Different types of traffic control plans can be proposed to reduce the traffic impact of planned special events. The simulationbased, multi- class, multi- modal traffic assignment model with departure time windows can be used to forecast the occurrence time and the level of traffic congestion produced by a planned special event. Using Cube Voyager, a mesoscopic and systematic assessment tool is developed to explore participant behaviours of planned special event for mode and departure time window choices, evaluate event scenarios, and duplicate what happened during previous planned special events for a better understanding of the related issues. Peak traffic volumes and traffic congestion generated by the planned special event are successfully estimated in this study. The impacts of a planned special event and the mitigation measures for various traffic control plans are also established successfully in this study. How far restrictions on turning movements are needed, when traffic control needs to start, and what value there is in the headway of feeder buses needs are also determined in these stage-by-stage traffic control plans. (C) 2017 The Authors. Published by Elsevier B.V.

127. Route Planning Methodology with Four-step Model and Dynamic Assignments

1. Horvath, Marton Tamas; Matrai, Tamas; Toth, Janos
2. TRANSP RES PROC

> Nowadays plenty of navigation and route guidance methodologies are available, based on real-time traffic information collected from technologies that have not been originally developed to measure road traffic parameters, for example, cellular and GPS data of users' mobile phones and their current travel demands. Traditional traffic estimation methodologies, such as the four-step model, are not frequently employed. This way, reliable traffic data can only be obtained for those areas where there are enough users. In our paper, we present a route guidance methodology that combines current transportation demands with the results of the traditional four-step model. The predicted traffic state of the network is calculated for every fifteen minutes of the day by using a dynamic assignment with predefined static demand matrices as a first assignment. When travelers use the route suggestion system, their demands are collected in an actual demand matrix for the same time interval. This matrix is then combined with the original static demand matrix for this period and then allocated to the network as a second assignment. The real-time traffic disruptions on the network are also taken into account. Users will be provided with route suggestions based on the combination of the results of the

> two assignments. The methodology is tested with real static demand and network data of Budapest, using an integrated multimodal transport model maintained by the BKK Centre for Budapest Transport. The actual demands are simulated, modelling various traffic situations.(C) 2017 The Authors. Published by Elsevier B.V.

136. Application of smart card data in validating a large-scale multi-modal transit assignment model

1. Tavassoli, Ahmad; Mesbah, Mahmoud; Hickman, Mark
2. PUBLIC TRANSPORT

> The accuracy of transit assignment plays an important role in the successful design and operation of a transit system. The majority of previous studies on validating transit assignment models has used limited survey data or has lacked a large-scale multimodal and high quality dataset. Considering the advantages of smart card [automatic fare collection (AFC)] systems, the aims of this study are to put forward a methodological framework to validate existing transit assignment models and to quantify the performance of these models. Our study combines data from three sources: the General Transit Feed Specification, an AFC system, and a strategic transport model from a large-scale multimodal public transport network, namely the South-East Queensland (SEQ) network in Australia. The AFC system in SEQ has provided a very large and highly accurate dataset on passenger boardings and alightings for the three transit modes of bus, rail and ferry. Following a data analysis, an origin-destination trip matrix is estimated for the AM peak period using AFC data as an input to the transit assignment model. Then, the results of the transit assignment model are compared with the actual passengers' route choices over the same period, at different levels of aggregation. The model performance is quantified by each route (and direction), by each segment of each route (and direction), and by each stop. The results indicate that relatively tighter thresholds are required to validate the transit assignment at the segment level than at the stop level. Furthermore, the validation results indicate that the greatest error is realized for the bus mode, while the level of accuracy in the rail mode is the best. The results suggest a segment-level analysis should be used as the most useful level of aggregation for future calibration and validation of transit assignment models.

137. Modelling joint activity-travel pattern scheduling problem in multi-modal transit networks

1. Fu, Xiao; Lam, William H. K.
2. TRANSPORTATION

> Over the past decades, many activity-based travel behaviour models have been proposed based on individuals' independent decision making. The modelling of individuals' joint activity/travel choices, however, has received less attention. In reality, both independent and joint activities/travels form individual's normal daily activity-travel patterns. Travel surveys have indicated that joint activity/travel constitutes an important part in individuals' daily activity-travel patterns. On this basis, explicit modelling of joint activity/travel choices is an essential component for long-term transport planning. In this study, an activity-based network equilibrium model is proposed for scheduling two-individual joint activity-travel patterns (JATPs) in congested multi-modal transit networks. The proposed model can be used to comprehensively investigate individuals' activity choices (e.g. activity start time and duration, activity sequence) and travel choices (e.g. departure time, route and mode) in multi-modal transit networks, including both independent ones and joint ones. The time-dependent JATP choice problem

> is converted into an equivalent static user equilibrium model by constructing a joint-activity-time-space (JATS) super-network platform. Joint travel benefit is modelled by incorporating a commonality factor in the JATP utility. A solution algorithm without prior JATP enumeration is proposed to solve the JATP scheduling problem on the JATS super-network. Numerical results show that individuals' independent and joint activity/travel choices can be simultaneously investigated by the proposed model. The impacts of joint travel benefit on individuals' independent and joint activity-travel choices are explicitly investigated.

138. Analysis of multimodal two-dimensional urban system equilibrium for cordon toll pricing and bus service design

1. Li, Zhi-Chun; Wang, Ya-Dong
2. TRANSPORT RES B-METH

> This paper presents a multimodal urban system equilibrium model to address cordon toll pricing and bus service design issues in a two-dimensional monocentric city. Commuters are assumed to travel by auto or bus from their home locations to their workplace located in the city center through a ring-radial routing system. Auto users must pay tolls when passing through the cordons installed on the radial major roads. The multimodal two-dimensional urban system equilibrium is first formulated and its properties are analytically explored. A social welfare maximization model that simultaneously determines the optimal cordon toll location, toll level, bus service frequency and fare on each radial major road is then proposed. The effects of different tolling schemes (uniform and differential cordon-based, first-best, and no toll) on the multimodal urban system are also examined and compared.

144. Remote park-and-ride network equilibrium model and its applications

1. Liu, Zhiyuan; Chen, Xinyuan; Meng, Qiang; Kim, Inhi
2. TRANSPORT RES B-METH

> Existing park-and-ride (P&R) sites are usually located near a train/bus station where construction and operation costs are considerably high. Thus, this paper proposes a new P&R service mode, Remote P&R (RPR), where the car park locates in a suburban area with lower land value. Dedicated express bus service is used to connect this site and a nearby train station. To quantitatively evaluate the impacts of RPR on the network flows, a combined modal split and traffic assignment model (CMSTA) is developed, where a cross-nested logit (CNL) model is adopted to cope with the mode similarity. The problem is formulated as a convex programming model and solved by the Evans algorithm, and then extended to asymmetric path-based cases, where a variational inequality (VI) model is built and solved by a self-adaptive gradient projection (SAGP) algorithm. Taking the CMSTA as the lower level and multimodal stochastic system optimum (MSSO) as the objective, we further develop a mathematical programming model with equilibrium constraints (MPEC) for the optimal network design of RPR. Based on an origin-based reformulation of the MPEC model, an exact solution method based on the nonlinear valid inequalities (NVI) is applied. Numerical examples demonstrate that the RPR services can significantly influence network users' travel decisions, promote the usage of public transportation and mitigate traffic congestion in the congested area of metropolitan cities.

147. Concurrent Estimation of Origin-Destination Flows and Calibration of Microscopic Traffic Simulation Parameters in a High-Performance Computing Cluster

1. Omrani, Reza; Kattan, Lina
2. J TRANSP ENG A-SYST

> This paper is aimed at developing an optimization framework for the concurrent calibration of demand and supply parameters in a dynamic traffic assignment (DTA) model. The proposed approach calibrates route choice, along with drivers' behavioral parameters, and estimates origin-destination (OD) flows in a large-scale network in a Paramics microscopic traffic simulation model. A mathematical formulation is defined to quantify the reliability of the observations. A genetic algorithm (GA) is selected as a suitable solution algorithm for the resulting nonlinear stochastic optimization problem. The application of the proposed methodology is implemented in the large-scale network in the business district core of downtown Toronto, Ontario, Canada. For this network, the emerging traffic surveillance data from in-vehicle navigation system technology provide an enriched source of disaggregated speed data. The empirical results from various experiments support the hypothesis that incorporating in-vehicle navigation system speed data can improve the calibration accuracy and minimize the reliance of the calibration process on a priori OD flows. The quality of the solution and convergence speed of a GA is further enhanced by dividing the GA population into multiple demes and running the GA on a high-performance computing cluster (HPCC) with multiple processors (i.e.,parallel distributed GA, PDGA). In addition, this research takes a further step toward analyzing the temporal variations of the driving behavior of travelers. The case study establishes an example for modelers and practitioners who are interested in calibrating a large-scale traffic simulation model. The developed simulation model for traffic has the potential to serve as a test bed on a HPCC for more efficient computation and integration with other optimization tools such as GAs. (C) 2017 American Society of Civil Engineers.

149. Day-to-day modal choice with a Pareto improvement or zero-sum revenue scheme

1. Guo, Ren-Yong; Szeto, W. Y.
2. TRANSPORT RES B-METH

> We investigate the day-to-day modal choice of commuters in a bi-modal transportation system comprising both private transport and public transit. On each day, commuters adjust their modal choice, based on the previous day's perceived travel cost and intraday toll or subsidy of each mode, to minimize their perceived travel cost. Meanwhile, the transportation authority sets the number of bus runs and the tolls or subsidies of two modes on each day, based on the previous day's modal choice of commuters, to simultaneously reduce the daily total actual travel cost of the transportation system and achieve a Pareto improvement or zero-sum revenue target at a stationary state. The evolution process of the modal choice of commuters, associated with the strategy adjustment process of the authority, is formulated as a dynamical system model. We analyze several properties of the dynamical system with respect to its stationary point and evolutionary trajectory. Moreover, we introduce new concepts of Pareto improvement and zero-sum revenue in a day-to-day dynamic setting and propose the two targets' implementations in either a prior or a posterior form. We show that, although commuters have different perceived travel costs for using the same travel mode, the authority need not know the probability distribution of perceived travel costs of commuters to achieve the Pareto improvement target. Finally, we give a set of numerical examples to show the properties of the model and the implementation of the toll or subsidy schemes. (C) 2018 Elsevier Ltd. All rights reserved.

150. Range-Constrained Traffic Assignment with Multi-Modal Recharge for Electric Vehicles

1. Zhang, Xiang; Rey, David; Waller, S. Travis; Chen, Nathan

2. NETW SPAT ECON

> Plug-in electric vehicles (PEVs) are sustainable alternatives to internal combustion engine vehicles thanks to the use of environmentally-friendly electric energy and the reduction of off-gas emissions. One of the major concerns associated with the adoption of PEVs is the distance limit, i.e. the fact that PEVs may not be able to complete trips without recharging. In this study, we propose to model the assignment of mixed-vehicular traffic of PEVs with two different charging capabilities accounting for PEV range constraints. We consider two recharge modes: charging stations with recharge time and modern charging lanes where PEVs are recharged automatically by traversing the lanes. The main objective of this study is to explore the influences of multi-modal recharge service provision on individual trips and network performance. First, a network transformation method is proposed to incorporate recharge decisions within the PEV route choice model. Second, we develop a novel convex programming formulation for mixed-vehicular traffic assignment accounting for en-route multi-modal recharge, derive mathematical properties and propose solution algorithms. In this rich traffic assignment framework, PEV route choice is represented as a resource-constrained shortest path subproblem with recharge time and we identify a suitable exact algorithm to solve this subproblem during the assignment process. Finally, computational experiments are conducted to demonstrate the performance of the proposed models and algorithms. The numerical results reveal that the incorporation of PEV multi-modal recharge has a significant impact on both route choice strategies and equilibrium flow patterns, wherein influencing factors include the distance limit, deployment of charging stations and charging lanes, and recharge time. In addition, we identify counter-intuitive configurations with regard to the way range constraints and recharge time reshape the equilibrium network flows.

153. Data-driven stochastic transit assignment modeling using an automatic fare collection system

1. Cheon, Seung Hoon; Lee, Changju; Shin, Seongil
2. TRANSPORT RES C-EMER

> In modern urban transit networks, buses and subways are not distinguished as different modes of transportation; this makes it challenging to analyze travel behaviors with multiple modes for the purpose of developing policies and plans. With the introduction of Automatic Fare Collection (AFC) systems, these modes are operated along a complex of links and nodes that constitute a multimodal transit network. Methods for analyzing travel behaviors in mass transit have been developed, but previous approaches fail to adequately reflect travel behaviors and network features (e.g., transfers, mode and route preferences). To overcome such limitations, this research proposes a smart card data-based analytical method with which travel behaviors can be efficiently and accurately examined. AFC systems provide a tremendous amount of data that contain detailed trip information, and using these data reinforces the reliability of the proposed data driven method. The proposed method of analysis involves four core processes: establishing a scheme for how multiple transit modes can be integrated into one multimodal transit network on the basis of information derived from the AFC system, selecting feasible paths, assigning trips using a stochastic approach, and verifying analytical results by comparing them with findings from trip datasets. This method was used to analyze monthly smart card data collected from the AFC system in 2009 in the greater Seoul area. Multimodal transit networks were constructed from 34,852 bus stops and 539 subway stations using smart card data, and in total, 3,614,875 trips were used in the analysis. The final model for stochastic transit assignment was developed using the proposed method, which was verified by comparing actual and assigned trips. The

> proposed method exhibits high accuracy (83.93%) and a high R-square value (0.981), which supports the strength of the proposed stochastic transit assignment model. The findings reveal new interesting research directions for exploration, such as developing more disaggregated models (e.g., for specific regions, times, and users), considering detailed transfer features (e.g., transferable boundaries, transfer facilities, and transfer times), confirming the method's applicability by testing it in other cities, and incorporating both multimodal transit and road networks into the proposed model.

157. A New Multi-Layer Distributed Approach for a Multi-objective Planning Problem

1. Mnif, Mouna; Bouamama, Sadok
2. PROCEDIA COMPUT SCI

> This paper introduces a new distributed approach to solve multi-objective planning problem applied to multimodal transport network planning (MTNP) problem. In this problem, the commodities should be transported on the international network by at least two different transport modes. The main goal is to find the best multimodal transportation modes and itineraries. The aim of the new approach has assured us that a distributed optimization. We split the MTNP problem into two sub-problems. These sub-problems are the assignment and the planning problems. Each sub-problem is solved at a corresponding layer. Each layer is executed by an agent. These agents interact, collaborate and communicate together to solve the MTNP problem. In this paper, we contribute by introducing a multi-layer distributed approach to solve real case's problems. Firstly, we define the MTNP problem as a distributed constraint satisfaction multi-criteria optimization problem (DCSMOP). Secondly, we show that the split of the main problem reduces the computational complexity and the communication between the planner agent and the modes agents lead to faster convergence. The experimental results are proof of this work efficiently. This method proves their efficiency, according to the complexity of the problem and the exchange of information, the computational time and the solution quality. (C) 2019 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/) Peer-review under responsibility of KES International.

158. A Multi-mode Two-Level Transportation Model Based On Network Vulnerability

1. Hu Wen-jun; Zhou Xi-zhao
2. nan

> Traffic network assignment under road network vulnerability and traffic congestion has become a hot topic for many researchers in recent years. Starting from the complex network characteristics of urban roads and multi-mode traffic network assignment, this paper establishes a multi-mode bilevel transportation model based on network vulnerability which can better reflect different path choice behaviour in a vulnerable network. The upper level is a function of maximizing the capacity of a road network under the investment constraints of the traffic authorities. Its purpose is to minimize the impact of the network operation efficiency and performance after the links or paths are damaged. The lower level is a multi-mode traffic network equilibrium model, which is essentially a traveler behavior assignment problem. Finally, a numerical example is given to demonstrate the effectiveness of the multimodal traffic model based on vulnerability. The analysis results show that the two-level model considering vulnerability index reduces the impact of abnormal events on the performance of road network, and is conducive to the establishment of a more reliable and stable road network.

159. Open-Source Public Transportation Mobility Simulation Engine DTALite-S: A Discretized Space-Time Network-Based Modeling Framework for Bridging Multi-agent Simulation and Optimization

1. Tong, Lu; Pan, Yuyan; Shang, Pan; Guo, Jifu; Xian, Kai; Zhou, Xuesong
2. URBAN RAIL TRANSIT

> Recently, an open-source light-weight dynamic traffic assignment (DTA) package, namely DTALite, has been developed to allow a rapid utilization of advanced dynamic traffic analysis capabilities. Aiming to bridge the modeling gaps between multi-agent simulation and optimization in a multimodal environment, we further design and develop DTALite-S to simplify the traffic flow dynamic representation details in DTALite for future extensions. We hope to offer a unified modeling framework with inherently consistent space-time network representations for both optimization formulation and simulation process. This paper includes three major modeling components: (1) mathematic formulations to describe traffic and public transportation simulation problem on a spacetime network; (2) transportation transition dynamics involving multiple agents in the optimization process; (3) an alternating direction method of multipliers (ADMM)-based modeling structure to link different features between multi-agent simulation and optimization used in transportation. This unified framework can be embedded in a Lagrangian relaxation method and a time-oriented sequential simulation procedure to handle many general applications. We carried out a case study by using this unified framework to simulate the passenger traveling process in Beijing subway network which contains 18 urban rail transit lines, 343 stations, and 52 transfer stations. Via the ADMM-based solution approach, queue lengths at platforms, in-vehicle congestion levels and absolute deviation of travel times are obtained within 1560 seconds. The case study indicate that the open-source DTALite-S integrates simulation and optimization procedure for complex dynamic transportation systems and can efficiently generate comprehensive space-time traveling status.

161. Managed gating control strategy for emergency evacuation

1. Bu, Lei; Wang, Feng; Zhou, Xuesong; Yin, Chuanzhong
2. TRANSPORTMETRICA A

> This study developed a nonlinear programing optimization model to demonstrate the effectiveness of a gating control strategy for traffic operations in emergency management when the population within an affected subarea must be evacuated. Selected nodes and links on or near the subarea boundary with enhanced traffic access and flow capacities could be treated as gates for evacuation traffic to be guided through with a higher priority over the non-gate nodes/links. The objective function was to minimize the total travel cost and the total number of traffic conflicts for different control scenarios in the evacuation network. The effectiveness of the strategy was tested by using a small scale evacuation network with eight nodes and sixteen links, and then in a case study of a realistic evacuation network in the Gulf Coast area with nodes and links in multiple counties. The experimental study results showed that the gating control strategy could improve the performance of the evacuation by reducing the average travel time in evacuation trip routes and decreasing the number of conflicting traffic movements compared with an otherwise situation where evacuation trips are conducted based on 'shortest paths' without a gating control strategy.

164. A multi-modal network equilibrium model with captive mode choice and path size logit route choice

1. Wang, Guangchao; Chen, Anthony; Kitthamkesorn, Songyot; Ryu, Seungkyu; Qi, Hang; Song, Ziqi; Song, Jianguo
2. TRANSPORT RES A-POL

> In this paper, we consider captive mode travelers (those who have no other choices but rely on one specific travel mode for daily commuting trips) in a multi-modal network equilibrium (MMNE) problem. Specifically, the dogit model is adopted to account for captive mode travelers in the modal split problem, and the path-size logit (PSL) model is used to capture route overlapping effects in the traffic assignment problem. The dogit-PSL MMNE model is formulated as an equivalent entropybased mathematical programming (MP) problem, which admits solution existence and uniqueness. Three numerical examples are provided. The first example examines the effects of mode captivity and route overlapping on network performances and observes that accounting for captive mode travelers would produce different equilibrium states and hence the network performance indicators. The second example applies the dogit-PSL MMNE model for evaluating the exclusive bus lane (EBL) expansion plans, in which a consistent synthetic proportional index is proposed. Numerical results show that considering mode captivity may produce substantial impacts on the odds (up to 50 percent of odds in the given scenarios) of making different EBL line expansion decisions. The third example implements the dogit-PSL MMNE model in the Seoul network to show the applicability of the dogitPSL MMNE model in a real-size multi-modal system.

167. Calibrating a transit assignment model using smart card data in a large-scale multi-modal transit network

1. Tavassoli, Ahmad; Mesbah, Mahmoud; Hickman, Mark
2. TRANSPORTATION

> This paper describes a practical automated procedure to calibrate and validate a transit assignment model. An optimization method based on particle swarm algorithm is adopted to minimize a defined error term. This error term which is based on the percentage of root mean square error and the mean absolute percent error encompasses deviation of model outputs from observations considering both segment level as well as the mode level and can be applied to a large scale network. This study is based on the frequency-based assignment model using the concept of optimal strategy while any transit assignment model can be used in the proposed methodological framework. Lastly, the model is validated using another weekday data. The proposed methodology uses automatic fare collection (AFC) data to estimate the origin-destination matrix. This study combines data from three sources: the general transit feed specification, AFC, and a strategic transport model from a large-scale multimodal public transport network. The South-East Queensland (SEQ) network in Australia is used as a case study. The AFC system in SEQ has voluminous and high quality data on passenger boardings and alightings across bus, rail and ferry modes. The results indicate that the proposed procedure can successfully develop a multi-modal transit assignment model at a large scale. Higher dispersions are seen for the bus mode, in contrast to rail and ferry modes. Furthermore, a comparison is made between the strategies used by passengers and the generated strategies by the model between each origin and destination to get more insights about the detailed behaviour of the model. Overall, the analysis indicates that the AFC data is a valuable and rich source in calibrating and validating a transit assignment model.

171. Integrated simulation-based dynamic traffic and transit assignment model for large-scale network

1. Kamel, Islam; Shalaby, Amer; Abdulhai, Baher
2. CAN J CIVIL ENG

> Although the traffic and transit assignment processes are intertwined, the interactions between them are usually ignored in practice, especially for large-scale networks. In this paper, we build a simulation-based traffic and transit assignment model that preserves the interactions between the two assignment processes for the large-scale network of the Greater Toronto Area during the morning peak. This traffic assignment model is dynamic, user-equilibrium seeking, and includes surface transit routes. It utilizes the congested travel times, determined by the dynamic traffic assignment, rather than using predefined timetables. Unlike the static transit assignment models, the proposed transit model distinguishes between different intervals within the morning peak by using the accurate demand, transit schedule, and time-based road level-of-service. The traffic and transit assignment models are calibrated against actual field observations. The resulting dynamic model is suitable for testing different demand management strategies that impose dynamic changes on multiple modes simultaneously.

172. A many-to-many assignment game and stable outcome algorithm to evaluate collaborative mobility-as-a-service platforms

1. Pantelidis, Theodoros P.; Chow, Joseph Y. J.; Rasulkhani, Saeid
2. TRANSPORT RES B-METH

> As Mobility as a Service (MaaS) systems become increasingly popular, travel is changing from unimodal trips to personalized services offered by a platform of mobility operators. Evaluation of MaaS platforms depends on modeling both user route decisions as well as operator service and pricing decisions. We adopt a new paradigm for traffic assignment in a MaaS network of multiple operators using the concept of stable matching to allocate costs and determine prices offered by operators corresponding to user route choices and operator service choices without resorting to nonconvex bilevel programming formulations. Unlike our prior work, the proposed model allows travelers to make multimodal, multi-operator trips, resulting in stable cost allocations between competing network operators to provide MaaS for users. An algorithm is proposed to efficiently generate stability conditions for the stable outcome model. Extensive computational experiments demonstrate the use of the model to handling pricing responses of MaaS operators in technological and capacity changes, government acquisition, consolidation, and firm entry, using the classic Sioux Falls network. The proposed algorithm replicates the same stability conditions as explicit path enumeration while taking only 17 seconds compared to explicit path enumeration timing out over 2 hours.

176. Calibration of a transit route choice model using revealed population data of smartcard in a multimodal transit network

1. Kim, Ikki; Kim, Hyoung-Chul; Seo, Dong-Jeong; Kim, Jung In
2. TRANSPORTATION

> One of the major objectives of this study is to provide more realistic and accurate results related to transit passenger's route choice behavior by using population data of revealed preference from smartcard transaction records. The smartcard data of the Seoul city provides both boarding and alighting location and time, which can make possible to trace each passenger's actually used path

> trajectory with close to 100% market penetration of smartcard usage. This study built an abstract transit network with representative nodes by aggregating all near-by bus stops within walkable distance and with abstract paths by aggregating lines for a specific OD pair that run the same trajectory links by same transit modes. This complex and huge-scale transit network allowed to analyze the route choice behavior of transit passengers in a multimodal transit system that could not be found from the data of relatively small-size cities. This study selected OD pairs which had two or more alternative paths in order to analyze choice behavior requiring a plural alternative choice set. The number of the selected OD pairs are 124,393 pairs that are 33.9% of whole OD pairs that has two or more trip records. The calibration result showed that it is good statistically and logically to include the six explanatory variables in the utility function of the multinomial Logit model. Those are in-vehicle travel time, out-of-vehicle travel time, transfer penalty index, travel time reliability measure, and path circuity index.

183. Multi-Modal Combined Route Choice Modeling in the MaaS Age Considering Generalized Path Overlapping Problem

1. Li, Dawei; Yang, Min; Jin, Cheng-Jie; Ren, Gang; Liu, Xianglong; Liu, Haode
2. IEEE T INTELL TRANSP

> In the MaaS (Mobility as a Service) age, the alternatives of route choice for a trip will not be the single mode paths, but the combined routes utilizing more than one travel mode in the multi-modal transportation systems. When modeling the multi-modal combined route choices, alternative routes are correlated not only because of the overlapping of physical links, but also because of the overlapping of travel modes. We define this problem as the generalized path overlapping problem. To address the generalized overlapping problem, a multi-modal logit kernel (MLK) model is proposed to explicitly consider the correlations of unobserved utilities of combined routes. In this model, the unobserved utilities of combined routes are divided to two parts, the link specific parts and the independent route specific parts. The link specific parts are further divided to two parts: physical link specific and the mode specific. The generalized path overlapping problem is captured by the sharing of these two parts of unobserved link utilities. Based on this model, the stochastic user equilibrium on multi-model transport networks is represented as a fixed-point problem. Numerical studies are designed to illustrate the effects of incorporating generalized overlapping problem on disaggregated route choice prediction and aggregated traffic flow assignment. With different settings of physical link and mode specific error terms, the variations of disaggregated route choice predictions and aggregated traffic flows are discussed. It is found that, the generalized overlapping problem can be captured by the proposed model and significantly affect both the individual route choice predictions and aggregated traffic flows at equilibrium.

185. A mixed-equilibrium model of individual and household activity-travel choices in multimodal transportation networks

1. Vo, Khoa D.; Lam, William H. K.; Li, Zhi-Chun
2. TRANSPORT RES C-EMER

> This paper develops a novel household-oriented activity-based mixed-equilibrium model for estimating individual and household activity-travel choices in multimodal transportation networks with interactions between private car and public transit modes. In the novel model, household members with heterogeneous errors of perception on the time-dependent utility of different activity types make

> daily joint/solo activity-travel choices in a mixed-equilibrium manner, which maximizes either perceived household utility or perceived individual utility. A logit-based stochastic choice model is developed to capture the mixed equilibrium with heterogeneous errors of perception and used to predict the choices of alternative joint activity-travel paths (JATPs) on a supernetwork platform. Based on this stochastic JATP choice model, the mixed-equilibrium model is formulated as an equivalent variational inequality (VI) problem and solved using a modified diagonalization method. This converts the time-dependent activity-travel scheduling problem into an equivalent static traffic assignment problem on JATPs. The conditions required for the existence and uniqueness of a solution to the equivalent VI problem in terms of a JATP flow pattern are also identified. Numerical examples are provided to illustrate the model's merits and its applications for examining the effect of the coronavirus disease 2019 (COVID-19) pandemic.

194. Evolution of multimodal final user equilibrium considering public transport network design history

1. Ameli, Mostafa; Lebacque, Jean Patrick; Leclercq, Ludovic
2. TRANSPORTMETRICA B

> Analysing the properties of a network equilibrium can help to have a better view about network state, robustness, and the effect of any variation in the network. This study investigated the impacts of network design history on day-to-day multimodal user equilibrium. In particular, we analyze the long-term evolution of the network, including opening new multimodal options and its impacts on the final network equilibrium. First, the analysis focuses on static network loading with different successive configurations. Then, a more realistic setting is studied by simulation. A large-scale multimodal network with the flexible opening over time of three possible transport facilities shows that the final equilibrium is not unique; more importantly, significant differences can be observed in public transportation occupancy, while user equilibrium is enforced in all situations. Some solutions prove to be better from the collective viewpoint (shorter total travel time), thus giving new insight into public transport planning.