

1. Incorporating personalization and bounded rationality into stochastic transit assignment model

1. Jiang, Yu; Ceder, Avishai (Avi)

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

The use of smartphone applications (apps) to acquire real-time information for trip planning has become and progressively continues becoming a more instinctive behavior among public transport (PT) users. Thus, it becomes an integral part of the design and management of PT systems, but corresponding transit assignment models for improving the prediction of passenger ridership have yet to be developed. This work proposes a novel stochastic transit assignment model that predicts passenger ridership. Two new features are incorporated into a transit assignment model, namely, personalization and bounded rationality. Personalization refers to a personalized routeranking methodology so that the app recommends paths with respect to a traveler's preference considering various PT attributes. Bounded rationality is modeled over three route-choice strategies representing different levels of cognitive effort exercised by a traveler in selecting a path from the set of paths recommended by the app. The transit assignment model is formulated as a fixed-point problem. Because the mapping function of the fixed-point formulation is not necessarily continuous, the model constructs an approximated fixed point existing under certain measures of discontinuity. The method of successive averages (MSA) is applied to solve the problem. Numerical studies are conducted to demonstrate the properties of the new transit assignment model, the effect of demand on the path choice probability, and the effect of passengers' heterogeneity on the convergence of the algorithm. The results reveal that, with a personalized path recommendation, passenger's preferences could stabilize the differences of path choice probability when adopting route-choice strategies relying on the path order. In addition, although the MSA may not always converge and oscillate, the fluctuation is below the derived measure of discontinuity, indicating that an approximated fixed point can be found.

2. Temporal validation of a multimodal transit assignment model

1. Rahbar, Mohadeseh; Hickman, Mark; Mesbah, Mahmoud; Tavassoli, Ahmad

2. CASE STUDIES ON TRANSPORT POLICY

With the increasing demand and range of urban mobility, public transport systems are playing an increasingly important role in providing people with efficient and affordable access to education, employment, markets, and other key services. Public transport planners can predict passenger loads and levels of service by using transit assignment models. Therefore, having a consistent transit assignment model has become an important issue. In addition, estimating the path choice factors, considering that network cost attributes might be non-deterministic, is complicated. In view of these, this paper adapted a transit assignment model, based on the Bayesian Model proposed in the authors' recent study, to validate the results of the model for multimodal transit networks under uncertainty and random variations of path choice parameters. In that model, path choices are represented by a multinomial logit model, and its coefficients are estimated via a Markov Chain Monte Carlo (MCMC) method. In this paper, the path choice parameters of the model are first calibrated by the individual travel history data in the AM peak period, and then are used to predict the passenger flow on different paths in the PM peak period. Second, based on the percentage error between each posterior estimate and the actual observation from AFC data on the segment level, the path segments are categorized

into four groups. Then, by defining the segment attributes, the strengths and weaknesses of the model are analysed for the four groups.

3. Transit assignment: Approach-based formulation, extragradient method, and paradox

1. Szeto, W. Y.; Jiang, Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper uses the concept of approach proportion to propose a novel variational inequality (VI) formulation of the frequency-based transit assignment problem. The approach proportion is defined as the proportion of passengers leaving a node through its outgoing link. To solve the VI problem, an extragradient method with adaptive stepsizes is developed. Unlike the existing methods for solving the frequency-based transit assignment problem, the convergence of our method requires only the pseudomonotone and Lipschitz continuous properties of the mapping function in VI, and it is not necessary for the Lipschitz constant to be known in advance. A Braess-like paradox in transit assignment is also discussed, where providing new lines to a transit network or increasing the frequency of an existing line may not improve the system performance in terms of expected total system travel cost. Various numerical examples are given to illustrate some paradox phenomena and to test the performance of our proposed algorithm. (C) 2014 Elsevier Ltd. All rights reserved.

4. A note on logit choices in strategy transit assignment

1. Florian, Michael; Constantin, Isabelle
2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

Since it was first developed [see Spiess and Florian, Transp Res 23: 83-102 (1989)], the strategy-based transit assignment has been extensively used and its properties are well understood now. The computation of an optimal strategy is relatively fast and is comparable to the computation of a shortest path tree for one destination. However, since it is the solution of a linear program, it produces extremal solutions. As a consequence, the sensitivity analysis of strategy flows is not smooth. This work parallels the contribution of Nguyen et al. (Transp Sci 32: 54-64 1998) who developed a logit choice of strategies following a basic idea due to Dial (Transp Res 5: 88-111, 1971), in order to consider a larger variety of strategies by allowing walk choices at nodes of the transit network. Nevertheless, since the network representation used is different from the one used by Nguyen et al. (Transp Sci 32: 54-64, 1998), the development is different. This modified logit strategy transit assignment algorithm was shown to produce more realistic results in dense transit networks where relatively short walks are required for access to attractive alternative transit paths. It also models better access from centroids representing large zones.

5. A solution to the transit assignment problem

1. Bell, MGH; Schmöcker, JD
2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

This paper describes a capacity constrained frequency- or headway-based transit assignment model which, by relaxing the assumption of flow conservation, can consider within-day dynamics. The probability of failing to board a service due to insufficient capacity is taken into account in route choice. Passengers mingle on platforms, so that the probability of failing to board a service is not a function of origin, destination or time of arrival at the platform. The presence of common lines is not

taken into account. An example demonstrates the impact of the capacity constraint on the number of passengers boarding at each stop when passengers make risk-averse route choices.

6. Frequency Based Transit Assignment Models: Graph Formulation Study

1. Owais, Mahmoud; Ahmed, Abdou S.
2. IEEE ACCESS

Transit network design problem (TNDP) usually needs a recursive solution to successive transit assignment problems. Interestingly, the transit assignment problem is complicated with several unique criteria. In this study, we comprehensively review two well-known graphical transit assignment models from the literature. The first model is based on the hypergraph theory by Spiess and Florian (1989), and the second is the section transit network representation of De Cea and Fernandez (1993). The two assignment approaches are formulated in a single mathematical notation framework for the first time in the literature to understand the inherent differences better. We aim to bring attention again to these approaches for the upcoming TNDP studies since the most used transit assignment models in the TNDP are deficient in their basic assumptions compared with the considered models.

7. Calibrating a Bayesian Transit Assignment Model Using Smart Card Data

1. Rahbar, Mohadeseh; Hickman, Mark; Mesbah, Mahmoud; Tavassoli, Ahmad
2. IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS

Public transport planners can predict passenger loads and levels of service by applying the prior knowledge about the transit network and using transit assignment models. The individual travel history data available from automated fare collection (AFC) systems bring the opportunity of understanding the individual's travel behavior, which is necessary to develop a transit assignment model. By combining the prior knowledge about the transit network with the AFC data, a transit assignment model can be calibrated. This paper proposes a Bayesian hierarchical model to estimate attributes of travel time components and to calibrate a transit assignment model. In this model, route choices are represented by a multinomial logit model, and its coefficients are estimated via a Markov chain Monte Carlo method. The proposed model is specified in two ways, and in order to consider travel time variability, it is assumed that travel time on links follows a gamma distribution. In the first specification, route choice variables and parameters are the same for all transit modes of bus, train, and ferry. In the second specification, mode-specific route choice variables and parameters are defined. In order to assess the model fitness, the root-meansquare error (RMSE) between each posterior estimate and the actual observation is computed. The lowest %RMSE belongs to the third-model specification (at 15%), which indicates its high predictive power.

8. Dynamic stochastic transit assignment with explicit seat allocation model

1. Sumalee, Agachai; Tan, Zhijia; Lam, William H. K.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes a stochastic dynamic transit assignment model with an explicit seat allocation process. The model is applicable to a general transit network. A seat allocation model is proposed to estimate the probability of a passenger waiting at a station or on-board to get a seat. The explicit seating model allows a better differentiation of in-vehicle discomfort experienced by sitting and standing passengers. The paper proposes simulation procedures for calculating the sitting probability

of each type of passengers. A heuristic solution algorithm for finding an equilibrium solution of the proposed model is developed and tested. The numerical tests show significant influences of the seat allocation model on equilibrium departure time and route choices of passengers. The proposed model is also applied to evaluate the effects of an advanced public transport information system (APTIS) on travellers' decision-making. (c) 2009 Elsevier Ltd. All rights reserved.

9. Logit-based transit assignment: Approach-based formulation and paradox revisit

1. Sun, S.; Szeto, W. Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes an approach-based transit assignment model under the assumption of logit-based stochastic user equilibrium (SUE) with fixed demand. This model is proven to have a unique solution. A cost-averaging version of the self-regulated averaging method (SRAM) is developed to solve the proposed approach-based SUE transit assignment problem. It is proven that the algorithm converges to the model solution. Numerical examples with discussions are presented to investigate the model properties, a paradoxical phenomenon due to the stochastic nature of the model, capacity paradox, and the performance of the proposed algorithm. The sensitivity analysis of different model and algorithm parameters are performed. A performance comparison between the cost-averaging SRAM, the flow-averaging SRAM, and the method of successive averages is made. The proposed methodology is demonstrated to be able to solve the Winnipeg transit network. (C) 2018 Elsevier Ltd. All rights reserved.

10. Modeling Stochastic Overload Delay in a Reliability-Based Transit Assignment Model

1. Shen, Liang; Shao, Hu; Li, Cuijie; Sun, Weiwei; Shao, Feng
2. IEEE ACCESS

In this paper, we develop a reliability-based transit assignment model with capacity constraints that adopt a new stochastic overload delay formulation. The in-vehicle travel times and waiting times are set to random variables. We adopt the statistical characteristics of the normal distribution to model the stochastic overload delay. The stochastic overload delay gradually varies as the passenger flow changes. A method is developed based on the method of successive averages algorithm to solve the reliability-based transit assignment model. Moreover, numerical experiments are conducted to illustrate the properties of the proposed model and the efficiency of the proposed algorithm.

11. A solution algorithm for capacity restrain transit assignment with elastic demand

1. Lei, QS; Tang, ZM; Jiang, DQ
2. PROCEEDINGS OF 2003 INTERNATIONAL CONFERENCE ON MANAGEMENT SCIENCE & ENGINEERING, VOLS I AND II

This paper firstly analysis the urban transit network characteristics, and then a variational inequality model of the capacity restrain transit assignment with elastic demand is proposed. Based on penalty function method, A solution algorithm for the proposed model is presented. Finally, a numerical example is used to illustrate the application of the proposed model and solution algorithm.

12. 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.

13. A heuristic method for a congested capacitated transit assignment model with strategies

1. Codina, Esteve; Rosell, Francisca

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper addresses the problem of solving the congested transit assignment problem with strict capacities. The model under consideration is the extension made by Cominetti and Correa (2001), for which the only solution method capable of resolving large transit networks is the one proposed by Cepeda et al. (2006). This transit assignment model was recently formulated by the authors as both a variational inequality problem and a fixed point inclusion problem. As a consequence of these results, this paper proposes an algorithm for solving the congested transit assignment problem with strict line capacities. The proposed method consists of using an MSA-based heuristic for finding a solution for the fixed point inclusion formulation. Additionally, it offers the advantage of always obtaining capacity-feasible flows with equal computational performance in cases of moderate congestion and with greater computational performance in cases of highly congested networks. A set of computational tests on realistic small- and large-scale transit networks under various congestion levels are reported, and the characteristics of the proposed method are analyzed. (C) 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license. (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

14. A frequency based transit assignment model that considers online information and strict capacity constraints

1. Olikar, Nurit; Bekhor, Shlomo

2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

This paper proposes a frequency based transit assignment model that accounts for online information and strict capacity constraints. A heuristic is proposed to solve the problem, which first applies an unconstrained transit assignment procedure and then handles only the over-loaded transit line segments, re-assigning the surplus passengers. The developed procedure is efficient, requiring very short running times compared to existing capacity constrained transit assignment models. The model assumes passengers receive online information of both predicted arrival time and occupancy condition. Two cases of occupancy information are considered: (1) passengers are informed of the vehicle occupancy, and may change their route selection accordingly, (2) passengers have no occupancy information and in case their boarding is denied, they are enforced to choose a later departing alternative. The model is applied for the Winnipeg network, and as expected the inclusion of capacity constraints increases the average travel time compared to the unconstrained model. However, prior knowledge of the occupancy condition was found to reduce the additional travel time. This result emphasizes the potential benefits of providing occupancy information to passengers.

15. A Learning-Based Day-to-Day Dynamics Model for Frequency-Based Transit Assignment

1. Lin, Yuqian; Yang, Min

2. CICTP 2019: TRANSPORTATION IN CHINA-CONNECTING THE WORLD

Passengers' travel experience on previous days will potentially influence their transit route choices on the next day. The day-to-day information is an important reference for decision-making of the transit assignment. This paper investigates the frequency-based transit assignment problem in a learning-based, day-to-day dynamics environment taking the learning and prediction behavior into consideration. The passengers' route cost updating, as well as the flow updating, are explicitly considered and incorporated in the day-to-day learning process of the transit assignment model. With the proposed cost updating and flow updating process, the frequency-based optimization model of the day-to-day transit assignment problem is formulated. Afterwards, the model is solved with the method of successive averages. Finally, the numerical experiment validates the effectiveness of the proposed model and algorithm. It is revealed that the passengers' flow evolution process will tend to be stable due to the day-to-day learning mechanism.

16. A New Solution Method for Solving Transit Assignment Problems

1. Le Luong Vuong; Tran Duc Quynh; Nguyen Quang Thuan

2. ADVANCES IN ENGINEERING RESEARCH AND APPLICATION

Congested transit assignment problems are crucial sub problems in planning public transportation systems. These problems are usually formulated in the form of non-convex optimization programs. In this work, we investigate the model given by De Cea et al. [3] that has been widely used by both practitioners and researchers. For solving this model, to the best of our knowledge, one must use a diagonalization technique in order to yield a symmetric assignment problem before applying a solution method. Consequently, the quality of the obtained solution would be possibly affected. The motivation of our work is to find a new efficient solution method to tackle directly the original assignment problem without diagonalization techniques. Basing on DC programming, we introduce a new solution method. The proposed algorithm is tested on the data given in [3]. Comparing with the existing method, the experimental results show that our approach is promising.

17. A stochastic transit assignment model using a dynamic schedule-based network

1. Tong, CO; Wong, SC

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Using the schedule-based approach, in which scheduled time-tables are used to describe the movement of vehicles, a dynamic transit assignment model is formulated. Passengers are assumed to travel on a path with minimum generalized cost which consists of four components: in-vehicle time; waiting time; walking time; and a time penalty for each line change. With the exception of in-vehicle time, each of the other cost components is weighted by a sensitivity coefficient which varies among travelers and is defined by a density function. This time-dependent and stochastic minimum path is generated by a specially developed branch and bound algorithm. The assignment procedure is conducted over a period in which both passenger demand and train headways are varying. Due to the stochastic nature of the assignment problem, a Monte Carlo approach is employed to solve the problem. A case study using the Mass Transit Railway System in Hong Kong is given to demonstrate the model and its potential applications. (C) 1998 Elsevier Science Ltd. All rights reserved.

18. A frequency based transit assignment model that considers online information

1. Olikar, Nurit; Bekhor, Shlomo

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper develops a frequency based transit assignment model considering that online information of predicted arrival times is available to passengers. The methodology is developed for two information levels: (1) full, where the arrival times are available for all intermediate stops in the candidate paths, and (2) partial, where the arrival times are available at the boarding stop only. Passengers are assumed to consider the estimated arrival times together with the expected travel time when choosing their path. The assignment procedure includes the finding of attractive paths, setting of route choice decision rules for different cases of predicted arrival times, and the probability calculation for these different cases. The developed model is illustrated by an application for the Winnipeg network. In comparison to the well-known optimal strategies method, the suggested model produced significantly different assignment results and a notable reduction in the total travel time. The results illustrate the potential impact of online information on assignment results, and emphasize the need for its consideration in planning models.

19. A review on transit assignment modelling approaches to congested networks: a new perspective

1. Fu, Qian; Liu, Ronghui; Hess, Stephane

2. PROCEEDINGS OF EWGT 2012 - 15TH MEETING OF THE EURO WORKING GROUP ON TRANSPORTATION

This paper reviews a number of studies on both frequency- and schedule-based transit assignment models that have been proposed by far, wherein various behavioural assumptions on a wide range of aspects are embedded. With a reinvestigation on the relationships and homogeneity between different modelling approaches, it explores the representative veins of the models, and thereby extends a new perspective to the existing reviews under a historical context. Meanwhile, both advantages and disadvantages of these methods are presented. On the strength of the analyses and discussions of the state-of-the-art transit assignment models, further research directions are suggested. (C) 2012 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the Program Committee

20. Optimisation of timetable-based, stochastic transit assignment models based on MSA

1. Nielsen, Otto Anker; Frederiksen, Rasmus Dyhr

2. ANNALS OF OPERATIONS RESEARCH

Public transport assignment models have increased in complexity in order to describe passengers' route choices as detailed and correctly as possible. Important trends in the development are (1) timetable-based assignment, (2) inclusion of feeder modes, (3) use of stochastic components to describe differences in passengers' preferences within and between purposes and classes (random coefficients), 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 Copenhagen-Ringsted Model (CRM), such a large-scale transit assignment model was developed and estimated. The Stochastic User Equilibrium problem was solved by the Method of Successive Averages (MSA). However, the model suffered from very large calculation times. The paper focuses on how to optimise transit assignment models based on MSA combined with a generalised utility function. Comparable tests are carried out on a large-scale network. The conclusion is that there is potential of optimising MSA-based methods. Examples of different approaches for this is presented, tested and discussed in the paper.

21. A quasi-dynamic capacity constrained frequency-based transit assignment model

1. Schmoecker, Jan-Dirk; Bell, Michael G. H.; Kurauchi, Fumitaka

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper presents a first approach to dynamic frequency-based transit assignment. As such the model aims to close the gap between schedule-based and frequency-based models. Frequency-based approaches have some advantages compared to schedule-based models, however, when modelling highly congested networks a static frequency-based approach is not sufficient as it does not reveal the peaked nature of the capacity problem. The central idea for dealing with the line capacity constraints is the introduction of a fail-to-board probability as in some circumstances passengers are not able to board the first service arriving due to overcrowding. The common line problem is taken into account and the search for the shortest hyperpath is influenced by the fail-to-board probability. An assumption that passengers mingle on the platform allows a Markov network loading process which respects the priority of on-board passengers with respect to those wishing to board. The study period is divided into several time intervals and those passengers who failed to board are added to the demand in the subsequent time interval and so might reconsider their route choice. Trips that are longer than one interval are also carried over to subsequent time intervals. The approach is first illustrated with a small example network and then with a case study relating to London, where transit capacity problems are experienced daily during the peak period. (C) 2008 Elsevier Ltd. All rights reserved.

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

1. Kamel, Islam; Shalaby, Amer; Abdulhai, Baher

2. CANADIAN JOURNAL OF CIVIL ENGINEERING

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.

23. A schedule-based transit assignment model addressing the passengers' choice among competing connections

1. Friedrich, M; Wekech, S
2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

Transit assignment procedures need to reflect the constraints imposed by line routes and timetables. They require specific search algorithms considering transfers between transit lines with their precise transfer time. The paper will present such an assignment procedure for transit networks using a schedule-based search algorithm. In contrast to existing schedule-based search methods employing a shortest-path algorithm, the described procedure constructs connections using branch & bound techniques. This approach produces better results in cases where slow but cheap or direct connections compete with fast alternatives which are more expensive or require transfers. At the same time it significantly reduces computing time, thus facilitating the use of timetable-based assignment for big networks.

24. Schedule-based transit assignment model with travel strategies and capacity constraints

1. Hamdouch, Younes; Lawphongpanich, Siriphong
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

In this paper, we propose a user equilibrium transit assignment model that takes into account transit schedules and individual vehicle capacities explicitly. The model assumes that passengers use travel strategies that can be adaptive over time and graphically represented as subgraphs. When loading a vehicle, on-board passengers continuing to the next stop have priority and waiting passengers can be loaded on a first-come-first-serve basis or in a random manner. The latter is appropriate when passengers mingle on waiting platforms. When a vehicle is full, passengers unable to board must wait for the next vehicle to arrive. The equilibrium conditions can be stated as a variational inequality involving a vector-valued function of expected strategy costs. Although the function is not necessarily continuous or monotonic, a solution to the variational inequality exists. To find a solution, we propose a method that takes successive averages as its iterates and generates strategies during each iteration by solving a dynamic program. Numerical examples empirically demonstrate that the algorithm converges to an equilibrium solution. (c) 2007 Elsevier Ltd. All rights reserved.

25. Automatic calibration of agent-based public transit assignment path choice to count data

1. Oliveros, Manuel Moyo; Nagel, Kai
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This work describes the calibration of a schedule-based transit assignment inside an iterative microscopic agent-based simulation. The calibration challenge implies that the behavioral rules should be modified in order to move the simulation closer to observed passenger counts. First, route choice set of agents is enriched with travel parameter utilities randomization. Secondly, the calibration interacts directly into the performance evaluation of individual daily plan of activities, so that the plan is also evaluated for its contribution to the count reproduction. In this way, appropriate plans from the calibration perspective can persist along simulation iterations. The Berlin public transport system with day-based counts is used as test scenario. The results show that the calibration approach can work with large scale scenarios, and that it is able to deal with the inter-temporal aspects implied by counts. (C) 2016 Elsevier Ltd. All rights reserved.

26. A Weibit-Based sequential transit assignment model based on hyperpath graph and generalized extreme value network representation

1. Du, Muqing; Cun, Dongyue; Chen, Anthony; Tan, Heqing
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This study aims to develop a weibit-based stochastic transit assignment model for situations in which passengers' travel choice strategies are stochastic. The weibit choice model, which was originally developed for the stochastic traffic assignment problem, is adapted using a hyperpath graph network representation. Unlike the traditional logit model, the weibit model can account for the homogeneous perception variance problem. Besides, a joint choice network representation originated from the network generalized extreme value (N-GEV) model, known as the GEV network, is adopted to depict the correlation among the arcs within the hypergraph consisting of all efficient hyperpaths. The GEV network uses a link-based parameter, the degree of membership, to capture the overlap effect, which is thus well incorporated with the link-based transit assignment approach. For implementation, a link-based stochastic network loading approach is proposed for solving the weibit-based transit assignment model in the sequential process. This sequential assignment approach does not need to enumerate and store the transit hyperpaths in the solution process. This model is then extended to a stochastic transit equilibrium model under congestion conditions, which is formulated as a fixed-point problem. Thus, a recent fast linesearch scheme, i.e., the Barzilai and Borwein step-size, is adopted for solving the stochastic transit equilibrium model. Numerical examples are provided to illustrate the features of the proposed weibit-based stochastic transit assignment model. A real transit network is used to demonstrate the algorithm efficiency and the detailed results of the weibit-based transit equilibrium model.

27. A stochastic congested strategy-based transit assignment model with hard capacity constraints

1. Codina, Esteve; Rosell, Francisca
2. 21ST EURO WORKING GROUP ON TRANSPORTATION MEETING (EWGT 2018)

This paper expands on the stochastic version of the strategy-based congested transit assignment problem described in Codina and Rosell (2017b), specifically by extending it to cases dealing with explicit line capacities. Following this previous work, the stochastic model with explicit line capacities takes into account the stochastic mean waiting times and in-vehicle travel times of passengers at stops during the standard scenario journey of the planning period. This slightly modified model is formulated also as a stochastic variational inequality derived from the deterministic version of the problem with

similar properties and characteristics, formulated by the authors in a previous work. For this stochastic capacitated model, two algorithms are presented which may take advantage of simplified simulation models for the bus stops in order to provide realistic mean waiting times for passengers at stops. Both algorithms can be easily adapted to the case of the model with non-strict capacities by Codina and Rosell (2017b). (C) 2019 The Authors. Published by Elsevier Ltd.

28. A new schedule-based transit assignment model with travel strategies and supply uncertainties

1. Hamdouch, Younes; Szeto, W. Y.; Jiang, Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes a new scheduled-based transit assignment model. Unlike other schedule-based models in the literature, we consider supply uncertainties and assume that users adopt strategies to travel from their origins to their destinations. We present an analytical formulation to ensure that on-board passengers continuing to the next stop have priority and waiting passengers are loaded on a first-come-first-serve basis. We propose an analytical model that captures the stochastic nature of the transit schedules and in-vehicle travel times due to road conditions, incidents, or adverse weather. We adopt a mean variance approach that can consider the covariance of travel time between links in a space time graph but still lead to a robust transit network loading procedure when optimal strategies are adopted. The proposed model is formulated as a user equilibrium problem and solved by an MSA-type algorithm. Numerical results are reported to show the effects of supply uncertainties on the travel strategies and departure times of passengers. (C) 2014 Elsevier Ltd. All rights reserved.

29. A stochastic process approach for frequency-based transit assignment with strict capacity constraints

1. Teklu, Fitsum
2. NETWORKS & SPATIAL ECONOMICS

Transit assignment models represent the stochastic nature of waiting times, but usually adopt a deterministic representation route flows and costs. Especially in cities where transit vehicles are small and not operating to timetables, there is a need to represent the variability in flows and costs to enable planners make more informed decisions. Stochastic process (SP) models consider the day-to-day dynamics of the transit demand-supply system, explicitly modelling passengers' information acquisition and decision processes. A Monte Carlo simulation based SP model that includes strict capacity constraints is presented in this paper. It uses micro-simulation to constrain passenger flows to capacities and obtain realistic cost estimates. Applications of the model and its comparison with the De Cea and Fernandez (Transp Sci, 27:133-147, 1993) model are presented using a small network.

30. Schedule-based transit assignment model with vehicle capacity and seat availability

1. Hamdouch, Younes; Ho, H. W.; Sumalee, Agachai; Wang, Guodong
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

In this paper, we propose a new schedule-based equilibrium transit assignment model that differentiates the discomfort level experienced by sitting and standing passengers. The notion of seat allocation has not been considered explicitly and analytically in previous schedule-based frameworks. The model assumes that passengers use strategies when traveling from their origin to their destination.

When loading a vehicle, standing on-board passengers continuing to the next station have priority to get available seats and waiting passengers are loaded on a First-Come-First-Serve (FCFS) principle. The stimulus of a standing passenger to sit increases with his/her remaining journey length and time already spent on-board. When a vehicle is full, passengers unable to board must wait for the next vehicle to arrive. The equilibrium conditions can be stated as a variational inequality involving a vector-valued function of expected strategy costs. To find a solution, we adopt the method of successive averages (MSA) that generates strategies during each iteration by solving a dynamic program. Numerical results are also reported to show the effects of our model on the travel strategies and departure time choices of passengers. (C) 2011 Elsevier Ltd. All rights reserved.

31. A new transit assignment model based on line and node strategies

1. Ren, Hualing; Song, Yingjie; Long, Jiancheng; Si, Bingfeng
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Passengers traveling on transit networks involve two kinds of decision-making strategies: deciding which lines are attractive at an origin or transfer node (denoted line strategy, LS), or deciding which node to transfer at when riding a line (denoted node strategy, NS). Combining these two strategies, this paper proposes a novel variational inequality formulation for the user equilibrium passenger assignment problem. The inclusion of the NS eliminates the need for passenger assignment on a large augmented graph, reducing the modeling complexity and making it easier to track all passengers' travel routes. Moreover, constraints on the maximal number of transfers-which are crucial in practical decision-making on transit networks-are explicitly included, further drastically reducing the set of passengers' feasible strategies. Furthermore, some extant strategy-based transit assignment models are shown to be a special case of the proposed model when the transfer constraint is removed. Finally, the properties of the proposed model are illustrated on a small network, and the model and algorithm exhibit huge advantages on the chosen transit subnetwork of Beijing.

32. Reliability-based stochastic transit assignment: Formulations and capacity paradox

1. Jiang, Y.; Szeto, W. Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This study develops link-based and approach-based variational inequality (VI) formulations for the frequency-based transit assignment with supply uncertainty, where link flows and flow on each outgoing link from each node are decision variables, respectively. Both the mean and variance of travel cost, including the covariance of in-vehicle travel costs, are captured in both formulations. To address the covariance of in-vehicle travel costs between different links on the same transit line, an augmented route-section network representation is developed, allowing us to apply the dynamic programming method to compute the value of the mapping function of the VI. The approach-based formulation can be solved by an extragradient method that only requires mild assumptions for convergence. It is found that the number of links carrying flow and equilibrium cost can be underestimated if supply uncertainty is not considered. The study also introduces and examines the capacity paradox, a phenomenon in which the network maximum throughput may be reduced after new transit lines are added to a transit network or after the frequency of an existing line is increased. It is found that the capacity paradox may or may not occur simultaneously with the Braess-like paradox, a phenomenon in which providing new transit lines to a network may deteriorate the network performance in terms of the total weighted sum of the mean and variance of travel cost of all of the passengers. The demand level and the degree of

risk aversion of passengers are the key factors that determine the occurrence of the capacity paradox. (C) 2016 The Authors. Published by Elsevier Ltd.

33. 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.

34. Reliability-based stochastic transit assignment with capacity constraints: Formulation and solution method

1. Szeto, W. Y.; Jiang, Yu; Wong, K. I.; Solayappan, Muthu
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper proposes a Linear Complementarity Problem (LCP) formulation for the reliability-based stochastic transit assignment problem with capacity constraints and non-additive link costs, where in-vehicle travel times and waiting times are uncertain. The capacity constraints are developed via the notions of effective capacity and chance constraints. An equivalent route-based linear program (LP) for the proposed problem is formulated to determine the patronage of each line section, critical links, critical service frequencies, unmet demand and the network capacity, which considers the risk-averse behavior of travelers. A solution method is developed, utilizing the IC-shortest path algorithm, the column generation technique, and the revised simplex method, to solve the proposed LP with guaranteed finite convergence. Numerical experiments are also set up to illustrate the properties of the problem and the application of the proposed model for reliability analysis. (C) 2011 Elsevier Ltd. All rights reserved.

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

1. Cheon, Seung Hoon; Lee, Changju; Shin, Seongil
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

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.

36. The multi-class schedule-based transit assignment model under network uncertainties

1. Zhang, Yuqing; Lam, William H. K.; Sumalee, Agachai; Lo, Hong K.; Tong, C. O.
2. PUBLIC TRANSPORT

Demand and supply uncertainties at schedule-based transit network levels strongly impact different passengers' travel behavior. In this paper, a new multi-class user reliability-based dynamic transit assignment model is presented. Passengers differ in their heterogeneous risk-taking attitudes towards the random travel cost. The stochastic characteristics of the main travel cost components (in-vehicle travel time, waiting time, and early or late penalty) are demonstrated by specifying the demand and supply uncertainties and their interactions. Passenger route and departure time choice is determined by each passenger's respective reliability requirements. Vehicle capacity constraint for random passenger demand is handled by an in-vehicle congestion parameter. The proposed model is formulated as a fixed-point problem, and solved by a heuristic MSA-type algorithm. The numerical result shows that the risk-taking attitude will impact greatly on passengers' travel mode and departure time choices, as well as their money and time costs. This model is also capable of generating transit service attributes such as the stochastic vehicle dwelling time and the deviated timetable.

37. Frequency-based transit assignment considering seat capacities

1. Schmoecker, Jan-Dirk; Fonzone, Achille; Shimamoto, Hiroshi; Kurauchi, Fumitaka; Bell, Michael G. H.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes a frequency-based assignment model that considers travellers probability of finding a seat in their perception of route cost and hence also their route choice. The model introduces a fail-to-sit probability at boarding points with travel costs based on the likelihood of travelling seated or standing. Priority rules are considered; in particular it is assumed that standing on-board passengers will occupy any available seats of alighting passengers before newly boarding passengers can fill any remaining seats. At the boarding point passengers are assumed to mingle, meaning that FIFO is not observed. as is the case for many crowded bus and metro stops, particularly in European countries. The route choice considers the common lines problem and an user equilibrium solution is sought through a Markov type network loading process and the method of successive averages. The model is first illustrated with a small example network before being applied to the inner zone of London's underground network. The effect of different values passengers might attach to finding a seat are illustrated. Applications of the model for transit planning as well as for information provision at the journey planner stage are discussed. (C) 2010 Elsevier Ltd. All rights reserved.

38. A Variational Inequality Reformulation of a Congested Transit Assignment Model by Cominetti, Correa, Cepeda, and Florian

1. Codina, Esteve
2. TRANSPORTATION SCIENCE

In the paper by Cominetti and Correa (2001) [Common-lines and passenger assignment in congested transit networks. *Transportation Sci.* 35(3):250-267], an extension to the common-lines problem for general multidestination networks under congestion is analyzed. Their transit equilibrium assignment model allows for a full representation of congestion effects caused by the variation of effective frequencies experienced by passengers at transit stops. This model is the first to address these characteristics consistently with the concept of strategies. In a subsequent paper by Cepeda, Cominetti, and Florian (2006) [A frequency-based assignment model for congested transit networks with strict capacity constraints: Characterization and computation of equilibria. *Transportation Res.* 40B(6):437-459], the computation of equilibrium is performed heuristically by the minimization of a gap function, using the method of successive averages. In this paper, a reformulation of this congested transit equilibrium assignment model is performed, demonstrating that the problem can be expressed as an equivalent variational inequality. The case of strictly capacitated transit networks is explored under the scope of this new reformulation, and new, broader conditions for the existence of solutions to this congested transit assignment model are determined.

39. A mesoscopic transit assignment model including real-time predictive information on crowding

1. Nuzzolo, Agostino; Crisalli, Umberto; Comi, Antonio; Rosati, Luca
2. JOURNAL OF INTELLIGENT TRANSPORTATION SYSTEMS

This article presents a mesoscopic transit assignment model suitable for real-time prediction of on-board passenger numbers in transit networks with real-time individual predictive information on travel time components and also including on-board crowding. The path choice modeling framework is

based on the reproduction of a travel strategy using random utility models that simulate both choices of departure time at origin and first access stop, and en-route choices of vehicle to board at stops. Such choices are based on attributes anticipated through a learning mechanism, which considers previous experiences and provides real-time predictive information. Within-day dynamic network loading considers vehicle capacity constraints, which allows the explicit modeling of fail-to-board events. Finally, results of an application on a real-size test network show the ability of the model to capture effects of providing individual predicted information on vehicle crowding.

40. Algorithm for equilibrium transit assignment problem

1. Babazadeh, A; Aashtiani, HZ
2. NETWORK MODELING 2005

Transit assignment is an important problem in the literature of transportation. Almost all competitive algorithms in this area are strategy based. For uncongested transit networks, the problem may be formulated into an optimization problem for which good solution algorithms exist. A variational inequality formulation of the problem with several solution methods is also presented in the literature for congested networks. This paper is devoted to solving a transit assignment problem based on complementarity formulation using path flows. The solution algorithm exploits the three concepts of decomposition, path generation, and linearization. The procedure has been applied on a large-scale realcase transit network under fixed travel times as well as How-dependent dwell times. Computational experiments show rapid convergence of the algorithm. Moreover, for the limited experiments performed, the computational time for the flow-dependent problem is only about twice that of the case for the fixed travel times, without an appreciable excess memory requirement.

41. Comparison of Agent-Based Transit Assignment Procedure with Conventional Approaches Toronto, Canada, Transit Network and Microsimulation Learning-Based Approach to Transit Assignment

1. Wang, Joshua; Wahba, Mohamed; Miller, Eric J.
2. TRANSPORTATION RESEARCH RECORD

The public transportation system, a key part of a multimodal transportation network, has been widely viewed as an efficient way to reduce road congestion and pollution. Public transportation planners use transit assignment models to forecast travel demand and service performance. As technologies evolve and smart transit systems become more prevalent, it is important that assignment models adapt to new policies, such as traveler information provision. This paper investigates three transit assignment tools that represent three approaches to modeling transit trip distribution over a network of fixed routes. These tools are the EMME/2 Transit Assignment Module (Module 535), commonly used by planners; Toronto, Canada, Transit Commission's transit assignment tool, MADITUC; and the newly developed Microsimulation Learning-based Approach to Transit Assignment (MILATRAS). These approaches range from aggregate, strategy-based frameworks to fully disaggregate microscopic platforms. MILATRAS presents a stochastic process approach (i.e., nonequilibrium based) for modeling within-day and day-to-day variations in the transit assignment process in which aggregate travel patterns can be extracted from individual choices. Although MILATRAS presents a different standpoint for analysis in comparison with equilibrium-based models, it still gives the steady state run loads. MILATRAS performs comparatively well with EMME/2 and MADITUC. In addition, MILATRAS presents a

policy-sensitive platform for modeling the effects of smart transit system policies and technologies on passengers' travel behavior (i.e., trip choices) and transit service performance.

42. Stochastic transit assignment with congested public transportation system

1. Lei, Quansheng; Chen, Jian
2. DYNAMICS OF CONTINUOUS DISCRETE AND IMPULSIVE SYSTEMS-SERIES B-APPLICATIONS & ALGORITHMS

This paper studies the congested transit assignment problem. We analyze transit network and study the augmented stochastic user equilibrium condition, a stochastic transit assignment model is proposed and a variational inequality model is built. The model can simultaneously predict how passengers will choose their optimal routes and estimate passenger flows in a congested transit networks. Based on the penalty function approach, an algorithm is presented. Finally, the algorithm is illustrated with a numerical example, the results show that the algorithm is quite satisfied.

43. Application of dwell time functions in transit assignment model

1. Aashtiani, HZ; Iravani, H
2. TRANSPORTATION PLANNING AND ANALYSIS 2002: PLANNING AND ADMINISTRATION

The transit assignment process applied as part of the development of the Tehran transportation model is described. The process includes development of various models for dwell time as a function of transit volume. Dwell time is the time a transit vehicle spends at a stop to allow passengers to alight and board. This method was implemented by using EMME/2 transportation planning software. The calculation of dwell time is necessary in modeling transit assignment because an accurate estimation of dwell time will lead to more precise transit assignment results. The area analyzed in the model comprises various transportation analysis zones in the city of Tehran. The model output was shown to be statistically significant. Calculations were found to be valid when compared with observed data.

44. A Stochastic Version of the Strategy-Based Congested Transit Assignment Model and a Technique by Smoothing Approximations

1. Codina, Esteve; Rosell, Francisca
2. ADVANCED CONCEPTS, METHODOLOGIES AND TECHNOLOGIES FOR TRANSPORTATION AND LOGISTICS

This paper develops a stochastic version for the strategy-based congested transit assignment problem stated by Cominetti and Correa (Trans. Sci. 35(3): 250-267, 2001). As a distinctive approach, this stochastic version takes into account stochastic mean waiting times of passengers at stops and in-vehicle travel times. The model is formulated as a stochastic variational inequality derived from the formulation of the deterministic version of the problem, also stated as a variational inequality problem, for which only a single solution method is known uptodate. Closely related with the stochastic model, and as a special case of it, a consistent smoothing approximation to the deterministic model is developed and it is shown that this approximation provides an alternative way of solving the deterministic model. It is also shown that both, the stochastic model and the smoothed approximation, can be solved by means of an adaptation of a path based method for the asymmetric traffic assignment problem. Computational tests have been carried out on several medium-large scale networks showing the viability of the method and its applicability to large scale transit models.

45. Transit Users' Route-Choice Modelling in Transit Assignment: A Review

1. Liu, Yulin; Bunker, Jonathan; Ferreira, Luis

2. TRANSPORT REVIEWS

This paper reviews the main studies on transit users' route choice in the context of transit assignment. The studies are categorized into three groups: static transit assignment, within-day dynamic transit assignment, and emerging approaches. The motivations and behavioural assumptions of these approaches are re-examined. The first group includes shortest-path heuristics in all-or-nothing assignment, random utility maximization route-choice models in stochastic assignment, and user equilibrium based assignment. The second group covers within-day dynamics in transit users' route choice, transit network formulations, and dynamic transit assignment. The third group introduces the emerging studies on behavioural complexities, day-to-day dynamics, and real-time dynamics in transit users' route choice. Future research directions are also discussed.

46. Transit assignment under crowded conditions

1. Tian, ZL; Yang, H; Lam, WHK

2. JOURNAL OF ADVANCED TRANSPORTATION

This paper presents a transit assignment algorithm for crowded networks. Both congestion in vehicles and queuing at stations are explicitly taken into account in predicting passenger flows for a fixed pattern of origin-destination trip demands. The overflow effects due to insufficient capacity of transit lines are considered to be concentrated at transit stations, while the in-vehicle congestion effects (or discomforts) are considered to be dependent on in-vehicle passenger volume. Overflow delay at a transit station is dependent on the number of excess passengers required to wait for the next transit car. We use a legit model to determine the split between passengers that chose to wait for the next transit car and passengers that chose to board on the alternative transit lines. The proposed algorithm predicts how passenger will choose their optimal routes under both queuing and crowded conditions.

47. 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. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

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. (C) 2016 Elsevier Ltd. All rights reserved.

48. An algorithm for the stochastic transit assignment model

1. Lei, QS; Tang, ZM; Chen, J
2. PROCEEDINGS OF THE 2001 INTERNATIONAL CONFERENCE ON MANAGEMENT SCIENCE AND ENGINEERING, VOLS I AND II

The paper propose an efficient algorithm for the stochastic transit assignment model that builds on the probit-based model in a congest transit network. Hereby, the problems with overlapping routes that occur in many public transport models can be avoided.

49. A capacity restraint transit assignment with elastic line frequency

1. Lam, WHK; Zhou, J; Sheng, ZH
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes a new formulation for the capacity restraint transit assignment problem with elastic line frequency, in which the line frequency is related to the passenger flows on transit lines. A stochastic user equilibrium transit assignment model with congestion and elastic line frequency is proposed and the equivalent mathematical programming problem is also formulated. Since the passenger waiting time and the line capacity are dependent on the line frequency, a fixed point problem with respect to the line frequency is devised accordingly. The existence of the fixed point problem has been proved. A solution algorithm for the proposed model is presented. Finally, a numerical example is used to illustrate the application of the proposed model and solution algorithm. (C) 2002 Elsevier Science Ltd. All rights reserved.

50. Dynamic transit assignment algorithms for urban congested networks

1. Crisalli, U
2. URBAN TRANSPORT V: URBAN TRANSPORT AND THE ENVIRONMENT FOR THE 21ST CENTURY

This paper reports fundamental aspects and implementative problems of dynamic transit assignment models. The first part describes the main features of the dynamic approach; successively dynamic network loading and equilibrium models are reported, as well as the relative algorithms of flow computation. Finally, algorithm convergence conditions are analysed and application results on a real-size test network are presented.

51. Incorporating Dynamic Bus Stop Simulation into Static Transit Assignment Models

1. Owais, Mahmoud; Hassan, Taher
2. INTERNATIONAL JOURNAL OF CIVIL ENGINEERING

This study provides a methodology to incorporate the dynamic bus stop simulation into a proposed static transit assignment model. It tries to combine the merits of the realism of dynamic models and the simplicity of static models in a single framework. An algorithm is developed to simulate any load profile of both passenger and bus arrivals. Then, the simulation results are used within the transit assignment process to allow a better line choice representation. A detailed illustrative example is given to validate the proposed assignment methodology performance. The resulted flows in some cases exceed lines capacity while conserving the static equilibrium principles. This capacity violation interprets the fact that some passengers may fail to board the first incoming bus of their desired line due to insufficient capacity. However, they wait until a vacant space is offered on the same line. In

addition, a benchmark problem is solved to ease the comparison between the proposed methodology and the existing methodologies. It shows the methodology capability of incorporating different waiting time models to produce passengers' flow on transit lines. It also indicates the importance of lines that might be neglected in other transit assignment models. This would highlight the methodology interpretation of passengers' behavior in transit networks.

52. Complementarity Formulation and Solution Algorithm for Auto-Transit Assignment Problem

1. Zarrinmehr, Amirali; Aashtiani, Hedayat Z.; Nie, Yu (Marco); Azizian, Hossein
2. TRANSPORTATION RESEARCH RECORD

In this paper, a combined model of auto-transit assignment is introduced based on two complementarity formulations in the literature. The model accounts for interactions between the auto and transit modes through non-separable asymmetric demand and cost functions. A path-based solution algorithm is presented based on the three ideas of decomposition, column generation, and linearization, which have proved to be effective in tackling large-size networks. Numerical results over the Chicago sketch network suggest that the algorithm converges quickly within the first iterations, but is less effective as the solution gets closer to the neighborhood of the equilibrium solution. The sluggish convergence behavior is attributed to the difficulty of searching the space of strategy-based transit assignment model.

53. The impact of centroid connectors on transit assignment outcomes

1. Manout, Ouassim; Bonnel, Patrick; Pacull, Francois
2. PUBLIC TRANSPORT

In transit modeling, access and egress conditions are often overlooked. The most common modeling technique of these conditions relies on the use of centroid connectors. This definition often uses the geographic position of zone centroids and sets constraints on the maximum number and length of connectors. This definition is subject to spatial aggregation issues and has already been proven to bias car assignment outcomes. The impact on transit assignment outcomes has not yet been demonstrated. The current paper investigates the statistical impact of connectors on transit assignment outcomes in an urban model of Lyon in France. Findings suggest that transit ridership, total passenger-kilometers and transit transfers are dependent on the definition of centroid connectors. Setting arbitrary values for the maximum number and length of connectors statistically affects transit results. The pattern and magnitude of this impact vary, however, between transit modes. The bus and rapid bus systems have been shown to be more sensitive towards the definition of connectors than the subway and the light rail systems. These findings question, to a certain extent, the validity and reliability of transit modeling outcomes.

54. Departure time and path choice models for intercity transit assignment

1. Nuzzolo, A; Russo, F
2. TRAVEL BEHAVIOUR RESEARCH: UPDATING THE STATE OF PLAY

In this chapter, the problem of intercity and extra-urban transit assignment will be dealt with through a network approach which explicitly considers timetables, and a random utility choice model involving departure time and path. The spatial-temporal network used is diachronic, thus allowing dynamic

assignment of the demand. In the first part, after a general analysis of transit assignment models, the timetable and network assignment model formulated by the authors is described, reporting the user's behavioural hypothesis on which it is based. In the second part, the departure time and path choice model required are analysed to determine the penalty function of anticipation and delay, which must be inserted in the network model, and two random utility legit and probit models are reported and calibrated for home-work and home-school trips. In the final part, two applications of the test network model are described.

55. Multiagent learning-based approach to transit assignment problem - A prototype

1. Wahba, Mohammed; Shalaby, Amer
2. TRAVELER BEHAVIOR AND VALUES 2005

This paper presents an operational prototype-of an innovative framework for the transit assignment problem, structured in a multiagent way and inspired by a learning-based approach. The proposed framework is based on representing passengers and their learning and decisionmaking activities explicitly. The underlying hypothesis is that individual passengers are expected to adjust their behavior (i.e., trip choices) according to their experience with transit system performance. A hypothetical transit network, which consists of 22 routes and 194 stops, has been developed within a microsimulation platform (Paramics). A population of 3,000 passengers was generated and synthesized to model the transit assignment process in the morning peak period. Using reinforcement learning to represent passengers' adaptation and accounting for differences in passengers' preferences and the dynamics of the transit network, the prototype has demonstrated that the proposed approach can simultaneously predict how passengers will choose their routes and estimate the total passenger travel cost in a congested network as well as loads on different transit routes.

56. Transit Assignment Model Incorporating Bus Dwell Time

1. Sun, Leilei; Meng, Qiang; Liu, Zhiyuan
2. TRANSPORTATION RESEARCH RECORD

The transit assignment problem with consideration of bus dwell time was analyzed in this study. The links in a transit network can be classified into four types: onboard, alighting, boarding, and dummy links. These types reflect bus dwelling behavior at bus stations. Accordingly, the travel time functions on these links can be analyzed. This paper proposes a new equation for the bus dwell time at each bus station; the dwell time is the maximum value between the passengers' boarding time and alighting time. An approach based on dynamic programming is used to describe the equilibrium passenger flow in the transit network. A gap function is proposed for formulating the equilibrium passenger flow, which can be solved with the revised optimal strategy algorithm and the method of successive averages. Two numerical examples in which the bus dwell time function is calibrated with real survey data are adopted. These examples validate the proposed methodology.

57. SCHEDULE-BASED TRANSIT ASSIGNMENT MODEL IN TRANSIT NETWORKS WITH RECURRENT UNCERTAINTIES

1. Zhang, Yuqing; Lam, William H. K.; Sumalee, Agachai
2. TRANSPORTATION AND MANAGEMENT SCIENCE

This paper proposes a novel within-day dynamic transit assignment model in networks with both demand and service uncertainties. The transit demand uncertainty is due to day-to-day demand variation and passengers' stochastic arrival patterns while the transit service uncertainty is result from the stochastic dwelling times at stops and transit vehicle travel times on roads. The schedule-based transit assignment approach is adapted for modeling passengers' risk-taking behavior on their route choice problem in dynamic transit networks with uncertainties. A dynamic network loading procedure is carried out in a time-incremental manner embedding a stochastic process. The proposed model is formulated as a fixed-point problem in a diachronic network. A multiple successive averaging algorithm is designed with propagation on passenger loads and service configuration. The proposed model is finally tested in a small-size artificial transit network for illustration.

58. G-EMME/2: Automatic calibration tool of the EMME/2 transit assignment using genetic algorithms

1. Parveen, Mily; Shalaby, Amer; Wahba, Mohamed
2. JOURNAL OF TRANSPORTATION ENGINEERING

This research presents an automatic procedure for calibrating transit-assignment model parameters. The calibration process targets the optimal set of parameter values by ensuring that the assignment output volumes match ridership volumes obtained from on-board surveys. Due to the combinatorial nature of the problem of interest, the proposed calibration process is automated using genetic algorithm techniques to find the best values for parameters through minimizing a misfit function. This study presents the new G-EMME/2 tool, which is an automatic calibration tool designed to find the optimal set of values for the transit-assignment model parameters implemented in the EMME/2 transportation planning software. The G-EMME/2 tool was applied to the Toronto transit network, and the five EMME/2 aggregate transit-assignment model parameters were estimated. The results are very encouraging. This research is an attempt to help automate the tedious process of calibrating transit assignment models.

59. Learning-based framework for transit assignment modeling under information provision

1. Wahba, Mohamed; Shalaby, Amer
2. TRANSPORTATION

The modeling of service dynamics has been the focus of recent developments in the field of transit assignment modeling. The emerging focus on dynamic service modeling requires a corresponding shift in transit demand modeling to represent appropriately the dynamic behaviour of passengers and their responses to Intelligent Transportation Systems technologies. This paper presents the theoretical development of a departure time and transit path choice model based on the Markovian Decision Process. This model is the core of the Mlcosimulation Learning-based Approach to TRansit Assignment. Passengers, while traveling, move to different locations in the transit network at different points in time (e.g. at stop, on board), representing a stochastic process. This stochastic process is partly dependent on the transit service performance and partly controlled by the transit rider's trip choices. This can be analyzed as a Markovian Decision Process, in which actions are rewarded and hence passengers' optimal policies for maximizing the trip utility can be estimated. The proposed model is classified as a bounded rational model, with a constant utility term and a stochastic choice rule. The model is appropriate for modeling information provision since it distinguishes between individual's experience with the service performance and information provided about system dynamics.

60. Learning and Adaptation in Dynamic Transit Assignment Models for Congested Networks

1. Cats, Oded; West, Jens
2. TRANSPORTATION RESEARCH RECORD

The distribution of passenger demand over the transit network is forecasted using transit assignment models which conventionally assume that passenger loads satisfy network equilibrium conditions. The approach taken in this study is to model transit path choice as a within-day dynamic process influenced by network state variation and real-time information. The iterative network loading process leading to steady-state conditions is performed by means of day-to-day learning implemented in an agent-based simulation model. We explicitly account for adaptation and learning in relation to service uncertainty, on-board crowding and information provision in the context of congested transit networks. This study thus combines the underlying assignment principles that govern transit assignment models and the disaggregate demand modeling enabled by agent-based simulation modeling. The model is applied to a toy network for illustration purposes, followed by a demonstration for the rapid transit network of Stockholm, Sweden. A full-scale application of the proposed model shows the day-to-day travel time and crowding development for different levels of network saturation and when deploying different levels of information availability.

61. Timetable-based transit assignment using branch and bound techniques

1. Friedrich, M; Hofsaess, I; Wekeck, S
2. TRAVEL PATTERNS AND BEHAVIOR; EFFECTS OF COMMUNICATIONS TECHNOLOGY: PLANNING AND ADMINISTRATION

Transit assignment procedures need to reflect the constraints imposed by line routes and timetables. They require specific search algorithms that consider transfers between transit lines with their precise transfer times. Such an assignment procedure is presented for transit networks using a timetable-based search algorithm. In contrast to existing timetable-based search methods employing a shortest-path algorithm, the described procedure constructs connections using branch and bound techniques. This approach significantly reduces computing time, thus facilitating the use of timetable-based assignment for large networks. At the same time, it produces better results in cases where slow but cheap or direct connections compete with fast connections that are more expensive or require transfers.

62. Departure Time Choice in Schedule-Based Transit Assignment

1. Friedrich, Markus; Schmaus, Matthias; Sauer, Jonas; Zundorf, Tobias
2. TRANSPORTATION RESEARCH RECORD

This paper investigates existing departure time models for a schedule-based transit assignment and their parametrization. It analyzes the impact of the temporal resolution of travel demand and suggests functions for evaluating the adaptation time as part of the utility of a path. The adaptation time quantifies the time between the preferred and the scheduled departure times. The findings of the analysis suggested that travel demand should be discretized into intervals of 1 min, with interval borders right between the full minute, that is, ± 0.5 min. It was shown that longer time intervals led to arbitrary run volumes, even for origin-destination pairs with just one transit line and a fixed headway. Although a linear relationship between adaptation time and adaptation disutility is a common assumption in several publications, it cannot represent certain types of passenger behavior.

For some trip purposes, passengers may be insensitive to small adaptation times, but highly sensitive to large adaptations. This requires a nonlinear evaluation function.

63. Determining Effective Sample Size to Calibrate a Transit Assignment Model: A Bayesian Perspective

1. Rahbar, Mohadeseh; Hickman, Mark; Mesbah, Mahmoud; Tavassoli, Ahmad
2. TRANSPORTATION RESEARCH RECORD

A transit assignment model is used to predict passenger loads in order to evaluate existing and future transit network scenarios. One fundamental issue affecting the calibration of a transit assignment model is the amount of data required. The present study is designed to determine the effect of different sample sizes on the accuracy level of the estimated passenger flow. A Bayesian model is adapted for transit assignment, and the sample size for three types of priors, namely: uninformative, informative, and overly informative, are examined. In order to assess the value of prior information on passenger flow, the root-mean-square error (RMSE) between each posterior estimate and the actual observation is computed. The posterior estimate that minimizes the %RMSE defines the effective sample size (ESS). This paper uses one day's automatic fare collection data from the South East Queensland (Australia) transit network to evaluate the effect of sample size and prior information on the posterior passenger flow estimates. The results show that it is not possible to determine the ESS for the Bayesian model with an uninformative prior. With an informative prior, the ESS is 50% of the population and, for the model with an overly informative prior, the ESS is 10% of the population. This means that the lack of prior information cannot simply be compensated by increasing the sample size in this Bayesian model. However, good prior information reduces the necessary sample size substantially.

64. Evaluating crowding in individual train cars using a dynamic transit assignment model

1. Peftitsi, Soumela; Jenelius, Erik; Cats, Oded
2. TRANSPORTMETRICA B-TRANSPORT DYNAMICS

As travel demand grows in many cities around the world, overcrowding in public transport systems has become a major issue and has many negative effects for both users and operators. Measures to address on-board congestion span from large-scale strategic investments (e.g. increasing infrastructure capacity), through tactical planning (e.g. stopping pattern) to real-time operational measures (e.g. information provision, gate and escalator control). Thus there is a need to evaluate the impact of these measures prior to their implementation. To this end, this study aims at capturing the effective capacity utilization of the train, by considering passengers' distribution among individual train cars into an agent-based simulation model. The developed model is validated and applied to a case study for the Stockholm metro network. The findings suggest that an increase in peak hour demand leads to a more even passenger distribution among individual train cars, which partially counteracts the increased disutility caused by the higher passenger volumes. Interestingly, the closure of the most popular entrance point at one of the stations leads to lower train crowding unevenness at the downstream stops and consequently reduces passengers' experienced discomfort. We find that the user cost is significantly underestimated when passenger distribution among cars is not accounted for.

65. Journey Levels in Strategy-Based Transit Assignment Modeling Integrated Transit Fares and More

1. Constantin, Isabelle; Florian, Daniel
2. TRANSPORTATION RESEARCH RECORD

The strategy-based transit assignment has been used extensively and its properties have been well understood since it was first developed. It can be used to model trip-additive generalized user costs, such as those incurred when waiting, boarding, walking, or traveling in-vehicle during a transit journey that can include transit fares. However, the solution algorithm is Markovian and does not directly incorporate the journey dependent state, such as the sequence of modes used to arrive at a node, which is necessary to model fares in integrated transit fare schemes. In practice, network constructions have been used to add state information to the strategies method; doing so adds complexity to and increases the size of the transit network model. Elaborate network constructions, which duplicate some or all of the transit network and add new transition links, may be necessary for more complicated fare schemes. An extension is proposed to the strategy-based transit assignment in which user costs can be made to vary along a trip according to a journey dependent state defined by a set of transit journey levels. The journey level enhanced strategy transit assignment algorithm allows explicit modeling of networkwide integrated fare schemes without network construction and provides a compact and flexible expression for the state transitions and corresponding generalized costs involved. The corresponding algorithm maintains the computational efficiency of the strategies method. Examples are provided together with computation results on small and large networks.

66. LARGE SCALE APPLICATIONS OF TRANSIT ASSIGNMENT ON CONGESTED NETWORKS

1. Florian, M.; He, S.
2. TRANSPORT DYNAMICS

The proper representation of route choice on transit networks that are subject to congestion is a continuous challenge in developed and developing countries. Theoretical contributions to the methodology for transit assignment methods that consider congestion have appeared in the literature (see for instance Cepeda et al. (2006) and Spiess and Florian (1989)). There are few documented successful applications of large scale applications of these methods and their validations using counts. The purpose of this paper is to present two large scale applications of the method described in Cepeda et al. (2006), which is based on optimal strategies, that considers discomfort functions aboard the vehicles and increased waiting times due to inability of transit travelers to board the first vehicle of a transit line to arrive. The applications described in detail in the paper are related to the planning networks of Santiago, Chile and London, UK.

67. Reliability-Based Transit Assignment for Congested Stochastic Transit Networks

1. Szeto, W. Y.; Solayappan, Muthu; Jiang, Yu
2. COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

This article proposes a nonlinear complementarity problem (NCP) formulation for the risk-averse stochastic transit assignment problem in which in-vehicle travel time, waiting time, capacity, and the effect of congestion are considered as stochastic variables simultaneously and both their means and variances are incorporated into the formulation. A new congestion model is developed and captured in the proposed NCP formulation to account for different effects of on-board passengers and passengers waiting at stops. A reliability-based user equilibrium condition is also defined based on the proposed generalized concept of travel time budget referred to as effective travel cost, and is captured in the

formulation. A column generation based algorithm is proposed to solve the NCP formulation. A survey was conducted to validate that the degree of risk aversion of transit passengers affects their route choices. Numerical studies were performed to demonstrate the problem and the effectiveness of the proposed algorithm. The results obtained show that underestimating the congestion effect and ignoring the risk aversion behavior can overestimate the patronage of transit service, which have profound implications on the profit of the operators involved and the development of transit network design models.

68. Urban transit assignment model based on augmented network with in-vehicle congestion and transfer congestion

1. Si, Bingfeng; Zhong, Ming; Yang, Xiaobao; Gao, Ziyu
2. JOURNAL OF SYSTEMS SCIENCE AND SYSTEMS ENGINEERING

This paper presents an augmented network model to represent urban transit system. Through such network model, the urban transit assignment problem can be easily modeled like a generalized traffic network. Simultaneously, the feasible route in such augmented transit network is then defined in accordance with the passengers' behaviors. The passengers' travel costs including walking time, waiting time, in-vehicle time and transfer time are formulated while the congestions at stations and the congestions in transit vehicles are all taken into account. On the base of these, an equilibrium model for urban transit assignment problem is presented and an improved shortest path method based algorithm is also proposed to solve it. Finally, a numerical example is provided to illustrate our approach.

69. Comparative analysis of transit assignment: evidence from urban railway system in the Tokyo Metropolitan Area

1. Kato, Hironori; Kaneko, Yuichiro; Inoue, Masashi
2. TRANSPORTATION

This paper empirically compares the performance of six traffic assignment methods using the same empirical dataset of route choice. Multinomial logit (MNL), structured multinomial probit (SMNP), user equilibrium (UE), logit-based stochastic user equilibrium (SUE), probit-based SUE, and all-or-nothing (AON) assignment methods are applied to the comparative analysis. The investigated methods include those with three types of error components in their cost functions and two types of flow dependencies. Four methods of generating the route choice set are also compared for use as stochastic traffic assignment methods. The revealed preference data of urban rail route choice in the Tokyo Metropolitan Area are used for the case analysis. The empirical case analysis shows that probit-based SUE provides the best accuracy but requires the longest computation time. It also shows that the heuristics used to generate the choice set influence the method's accuracy, while the incorporation of route commonality and in-vehicle congestion significantly improves its accuracy. Finally, the implications for practical rail planning are discussed on the basis of the analysis results.

70. Transit Assignment Modeling Approaches based on Interval Uncertainty of Urban Public Transit Net Impedance

1. Tan, Qian; Zhou, Xiangdong; Liu, Wusheng
2. TEHNICKI VJESNIK-TECHNICAL GAZETTE

The data of the regular bus in Shenzhen during October 2019 was taken as an example. The improved model for the public transportation assignment was established based on considering the interval uncertainty theory and the basic algorithm of interval value, and the interval value acquisition method of bus impedance is established, the Method of Successive Averages (MSA) algorithm is used to solve the problem. Finally, the error analysis of bus passenger flow assignment before and after the improvement of the model is carried out. It is found that the average absolute percentage error of the improved assignment model is 8.7% compared with the real value, while the average absolute percentage error is 10.9% when the impedance is invariant value, The result of passenger flow assignment under interval impedance is obviously better than that under certain impedance. On non-working days, when the bus passenger flow changes greatly, the bus passenger flow assignment result under interval impedance is better.

71. Frequency and Vehicle Capacity Determination using a Dynamic Transit Assignment Model

1. Cats, Oded; Gluck, Stefan
2. TRANSPORTATION RESEARCH RECORD

We integrate for the first time, to our knowledge, a dynamic transit assignment model into the tactical planning phase. The settings of service frequencies and vehicle capacities determine line capacity and have significant consequences for level-of-service and operational costs. The objective of this study is to determine frequency and vehicle capacity at the network level while accounting for the impact of service variations on users and operator costs. To this end, we propose a simulation-based optimization approach. The proposed model allows accounting for variations in service headways and crowding as well as their consequences for passenger flows distribution, all of which have not been accounted for in the tactical planning so far. Practical benefits of the model are demonstrated by an application to a bus network in the Amsterdam metropolitan area. This study contributes to the development of a new generation of methods that integrate reliability into the tactical planning phase to improve service quality.

72. Equilibrium model and algorithm of urban transit assignment based on augmented network

1. Si BingFeng; Zhong Ming; Sun HuiJun; Gao ZiYou
2. SCIENCE IN CHINA SERIES E-TECHNOLOGICAL SCIENCES

The passenger flow assignment problem for the urban transit network is relatively complicated due to the complexity of the network structure and many factors influencing the passengers' route and line choices. In the past three decades, many models have been proposed to solve the passenger flow assignment problem. However, the common-line problem remains challenging in transit flow assignment. In this paper, the characteristics of the urban transit network is analysed and a new technique of augmented network is proposed to represent the urban transit system. The purpose is to eliminate the complex common-line problem when modeling transit passenger flow assignment. Through this augmentation technique, the urban transit system can be represented by an augmented network-it then behaves like a simple network and can be used as a generalized network for traffic assignment or network analysis. This paper presents a user equilibrium model for the urban transit assignment problem based on such a technique. A numerical example is also provided to illustrate the approach.

73. A Capacity-Restraint Transit Assignment Model When a Predetermination Method Indicates the Invalidity of Time Independence

1. Ding, Haoyang; Bao, Yu; Luo, Sida; Shen, Hanxia; Wang, Wei; Long, Man

2. MATHEMATICAL PROBLEMS IN ENGINEERING

The statistical independence of time of every two adjacent bus links plays a crucial role in deciding the feasibility of using many mathematical models to analyze urban transit networks. Traditional research generally ignores the time independence that acts as the ground of their models. Assumption is usually made that time independence of every two adjacent links is sound. This is, however, actually groundless and probably causes problematic conclusions reached by corresponding models. Many transit assignment models such as multinomial probit-based models lose their effects when the time independence is not valid. In this paper, a simple method to predetermine the time independence is proposed. Based on the predetermination method, a modified capacity-restraint transit assignment method aimed at engineering practice is put forward and tested through a small contrived network and a case study in Nanjing city, China, respectively. It is found that the slope of regression equation between the mean and standard deviation of normal distribution acts as the indicator of time independence at the same time. Besides, our modified assignment method performs better than the traditional one with more reasonable results while keeping the property of simplicity well.

74. A frequency based transit assignment model that considers online information at the boarding stop

1. Olikar, Nurit; Bekhor, Shlomo

2. 2016 IEEE 19TH INTERNATIONAL CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS (ITSC)

This paper develops a frequency based transit assignment model, assuming that transit arrival times are available to the passenger at the boarding stop. The model considers the estimated arrival times together with the expected travel times, when selecting a path. The assignment procedure includes the setting of decision rules for different cases of arrival times, and the calculation of probabilities for these different cases. The model is applied on a real-size network, and the results are compared to the well-known optimal strategies method. The suggested model showed significantly different results and a notable reduction in the total travel time. The results illustrate the potential impact of online information on travel behavior, and emphasize the need of its consideration in assignment models.

75. A multi-class transit assignment model for estimating transit passenger flows-a case study of Beijing subway network

1. Si, Bingfeng; Fu, Liping; Liu, Jianfeng; Shiravi, Sajad; Gao, Ziyou

2. JOURNAL OF ADVANCED TRANSPORTATION

This paper describes a case study comparing a multi-class transit assignment model with its single class counterpart for estimating the passenger flows of the Beijing subway network-one of the largest railway transit networks in the world. Multi-class traffic assignment has been widely considered as a theoretically sound approach to capture the inherent variation in users' route choice behavior. However, few empirical studies have been devoted to showing the effectiveness of this approach in improving the accuracy of the underlying passenger flow estimation process. In this research, a passenger classification scheme is proposed on the basis of a dataset from a large stated preference survey conducted in the City of Beijing, China. Separate generalized cost functions are calibrated for

different classes of subway users in Beijing and applied in a multi-class transit assignment model for estimating passenger flows over a subway network. The case study has shown that the proposed multi-class approach resulted in significantly improved estimation results with an average estimation error of less than 15% on the transfer flows as compared with 30% for the single class model. Copyright (C) 2015 John Wiley & Sons, Ltd.

76. Validating Rail Transit Assignment Models with Cluster Analysis and Automatic Fare Collection Data

1. Zhu, Wei; Zhou, Feng; Huang, Jiajun; Xu, Ruihua
2. TRANSPORTATION RESEARCH RECORD

Passenger flow data are necessary for making and coordinating operational plans for urban rail transit (URT) systems; the availability and the service state of those systems directly influence the activity of a city and its people. Although many transit assignment models have been developed, the results of passenger flows estimated by these models as well as assumptions made in the estimation process, especially for large-scale, complex, and dynamically changing URT networks, had not been validated. This paper proposes a methodology that can validate existing URT assignment models by using automatic fare collection data and a cluster analysis technique. Initial applications to the URT system of Shanghai, China, which is one of the largest in the world, show that the proposed approach works well and can efficiently find the origin destination pairs in which passengers' route choices are misestimated by those assignment models. The analysis suggests that several factors result in errors (for the URT assignment model used in Shanghai). These factors include the threshold for the difference in travel costs, a misrepresentation of the transferring cost, and inadequate values for the standard deviation. This information is useful for detecting errors in existing URT assignment models, leading to improvements.

77. Research on the Multiroute Probit-Based Public Transit Assignment Model Based on Bus Stop

1. Mei, Zhenyu; Wang, Dianhai; Wang, Fujian; Chen, Jun; Wang, Wei
2. MATHEMATICAL PROBLEMS IN ENGINEERING

A public transit network differs from a general road network. The passenger flow of bus stops and the limited capacity of buses have a greater effect than road traffic flow on the running time of buses. As a result, conventional public transit assignment models that adopt the econometric road network path concept have numerous limitations. Based on the analysis, the generalized bus trip time chain is analyzed, and the concept of a congestion function is proposed to describe the relationship between trip resistance and flow in the current paper. On the premise of this study, the transit network resistance function is formed and the multiroute probit-based loading model is established. With using STOCH or Dial's algorithm, the process of distribution is proposed. Finally, the model is applied to the transit network assignment of Deqing Town in Zhejiang Province. The result indicates that the model can be applied to practical operations with high-precision results.

78. A general multi-agent modelling framework for the transit assignment problem - A Learning-Based Approach

1. Wahba, Mohammed; Shalaby, Amer
2. INNOVATIVE INTERNET COMMUNITY SYSTEMS

This paper presents the conceptual development of an innovative modelling framework for the transit assignment problem, structured in a multiagent way and inspired by a learning-based approach. The proposed framework is based on representing passengers and both their learning and decision-making activities explicitly. The underlying hypothesis is that individual passengers are expected to adjust their behaviour (i.e. trip choices) according to their knowledge and experience with the transit system performance, and this decision-making process is based on a mental model of the transit network conditions. The proposed framework, with different specifications, is capable of representing current practices. The framework, once implemented, can be beneficial in many respects. When connected with urban transportation models such as ILUTE - the effect of different land use policies, which change passenger demand, on the transit system performance can be evaluated and assessed.

79. RISK-AVERSIVE STOCHASTIC TRANSIT ASSIGNMENT

1. Jiang, Y.; Szeto, W. Y.; Wong, S. C.
2. TRANSPORTATION AND URBAN SUSTAINABILITY

nan

80. Deterministic time table transit assignment

1. Constantin, I; Florian, M; Spiess, H
2. NATIONAL TRANSPORT MODELS: RECENT DEVELOPMENTS AND PROSPECTS

nan

81. Hybrid Random Regret Minimization and Random Utility Maximization in the Context of Schedule-Based Urban Rail Transit Assignment

1. Li, Dewei; Gao, Yufang; Li, Ruoyi; Zhou, Weiteng
2. JOURNAL OF ADVANCED TRANSPORTATION

Route choice is one of the most critical passenger behaviors in public transit research. The utility maximization theory is generally used to model passengers' route choice behavior in a public transit network in previous research. However, researchers have found that passenger behavior is far more complicated than a single utility maximization assumption. Some passengers tend to maximize their utility while others would minimize their regrets. In this paper, a schedule-based transit assignment model based on the hybrid of utility maximization and regret minimization is proposed to study the passenger route choice behavior in an urban rail transit network. Firstly, based on the smart card data, the space-time expanded network in an urban rail transit was constructed. Then, it adapts the utility maximization (RUM) and the regret minimization theory (RRM) to analyze and model the passenger route choice behavior independently. The utility values and the regret values are calculated with the utility and the regret functions. A transit assignment model is established based on a hybrid of the random utility maximization and the random regret minimization (RURM) with two kinds of hybrid rules, namely, attribute level hybrid and decision level hybrid. The models are solved by the method of successive algorithm. Finally, the hybrid assignment models are applied to Beijing urban rail transit network for validation. The result shows that RRM and RUM make no significant difference for OD pairs with only two alternative routes. For those with more than two alternative routes, the performance of RRM and RUM is different. RRM is slightly better than RUM in some of the OD pairs, while for the other OD pairs, the results are opposite. Moreover, it shows that the crowd would only influence the regret

value of OD pair with more commuters. We conclude that compared with RUM and RRM, the hybrid model RURM is more general.

82. Capacitated transit assignment with loading priorities

1. Hamdouch, Y; Marcotte, P; Nguyen, S
2. MATHEMATICAL PROGRAMMING

In a transit network involving vehicles with rigid capacities, we advocate the use of strategies for describing consumer behavior. At each boarding node, a user sorts the transit lines in decreasing order of preference, and boards the first vehicle in this list whose residual capacity is nonzero. Since a user's position in the queue varies from day to day, the delay experienced is stochastic. This leads to an equilibrium problem where, at a solution, users are assigned to strategies that minimize their expected delay. This situation is formulated as a variational inequality, whose cost mapping is discontinuous and strongly asymmetric, due to the priority of current passengers over incoming users. We prove that the solution set is nonempty and provide numerical results obtained by an efficient solution algorithm.

83. Regional mass transit assignment with resource constraints

1. Carraresi, P; Malucelli, F; Pallottino, S
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper considers a mass transit system in a regional area. The problem of improving the quality of the service by decreasing the total passenger waiting time is studied. A model to improve the effectiveness of the system without worsening the cost (vehicles and duties) and the passenger assignment is proposed, along with a new definition of passenger assignment to support the proposed model. Copyright (C) 1996 Elsevier Science Ltd.

84. Optimization of service frequencies in bus networks with harmony search algorithm: An application on Mandl's test network

1. Ceylan, Huseyin; Ozcan, Tayfun
2. PAMUKKALE UNIVERSITY JOURNAL OF ENGINEERING SCIENCES-PAMUKKALE UNIVERSITESI MUHENDISLIK BILIMLERI DERGISI

In developing countries, efforts to increase the efficiency of bus transportation, which is the most common type of urban public transport systems, have been increasing in recent years. Many studies addressing the performance of bus systems focus on approaches to optimizing user and operator benefits. In this study, a bi-level simulation/ optimization model is developed to optimize service frequencies in urban bus networks. At the upper level, a meta-heuristic Harmony Search (HS) optimization technique based model is proposed for solving an objective function that represents operator and user costs. At the lower level, the transit assignment problem, which represents the distribution of demand over the transit network, is solved. In the proposed model, a time-table based transit assignment approach is used for the exact calculation of transfer wait times, and the transit assignment problem is solved using VISUM software based on a logit-based choice model. The developed model has been applied to a test network that is widely used in transit network design studies. The results show that the HS based model can be used effectively to solve the service frequency optimization problem.

85. ROUTE CHOICE IN CONGESTED TRANSIT NETWORKS: SOME RESULTS FROM LONDON

1. Bell, Michael G. H.; Schmoecker, Jan-Dirk; Lee, Chi
2. TRANSPORTATION IN THE INFORMATION AGE: PROCEEDINGS OF THE 7TH CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

This paper describes a novel approach to the transit network loading problem using absorbing Markov Chains. The approach handles congested transit networks, where some passengers will not be able to board the next service of a given line because of the absence of sufficient space on board. It is assumed that passengers coming from different origins and travelling to different destinations mingle on platforms, so that the probability of failing to board the next service is not a function of time. The network loading method becomes a transit assignment method when route choice behaviour is added. One approach is to assume that passengers tend to avoid routes where there is a higher probability of failure to board the next service of a given line. The results from Central London underground demonstrate the calculation of the number of passengers able to board when passengers on board have priority over passengers wishing to board. It is also shown how risk-averse route choice behaviour influences the equilibrium transit assignment.

86. The Theory of Transit Assignment: Basic Modelling Frameworks

1. Gentile, Guido; Florian, Michael; Hamdouch, Younes; Cats, Oded; Nuzzolo, Agostino
2. MODELLING PUBLIC TRANSPORT PASSENGER FLOWS IN THE ERA OF INTELLIGENT TRANSPORT SYSTEMS: COST ACTION TU1004 (TRANSITS)

nan

87. Boarding and Alighting in Frequency-Based Transit Assignment

1. Noekel, Klaus; Wekeck, Steffen
2. TRANSPORTATION RESEARCH RECORD

Several models of route choice in frequency-based assignment are compared for underlying assumptions on service regularity, passenger information, and choice set structure. Numerical results for some simple examples show that route splits differ significantly under different assumptions, so for practical applications the selection of the most suitable choice model is important and none of the models can be regarded as a good approximation for all possible assumptions. Sensitivity of route choice against perturbations of running times or service frequencies is another consideration, because a continuous response improves convergence in demand models with feedback. Finally, it is demonstrated that in terms of expected travel time, the decision about when to alight (and where to continue the journey) is just as important as the decision of which line to board.

88. Ridership estimation procedure for a transit corridor with new bus rapid transit service

1. Umlauf, Tadeas; Galicia, Luis David; Cheu, Ruey Long; Horak, Tomas
2. JOURNAL OF ADVANCED TRANSPORTATION

Ridership estimation is a critical step in the planning of a new transit route or change in service. Very often, when a new transit route is introduced, the existing routes will be modified, vehicle capacities changed, or service headways adjusted. This has made ridership forecasts for the new, existing, and modified routes challenging. This paper proposes and demonstrates a procedure that forecasts the

ridership of all transit routes along a corridor when a new bus rapid transit (BRT) service is introduced and existing regular bus services are adjusted. The procedure uses demographic data along the corridor, a recent origin-destination survey data, and new and existing transit service features as inputs. It consists of two stages of transit assignment. In the first stage, a transit assignment is performed with the existing transit demand on the proposed BRT and existing bus routes, so that adjustments to the existing bus services can be identified. This transit assignment is performed iteratively until there is no adjustment in transit services. In the second stage, the transit assignment is carried out with the new BRT and adjusted regular bus services, but incorporates a potential growth in ridership because of the new BRT service. The final outputs of the procedure are ridership for all routes and route segments, boarding and alighting volumes at all stops, and a stop-by-stop trip matrix. The proposed ridership estimation procedure is applicable to a new BRT route with and without competing regular bus routes and with BRT vehicles traveling in dedicated lanes or in mixed traffic. The application of the proposed procedure is demonstrated via a case study along the Alameda Corridor in El Paso, Texas. Copyright (c) 2015 John Wiley & Sons, Ltd.

89. TRANSIT ASSIGNMENT MODEL CONSIDERING THE RELIABILITY OF TRAVEL TIME

1. Harao, Akira; Kurauchi, Fumitaka; Shimamoto, Hiroshi
2. TRANSPORTATION STUDIES: SUSTAINABLE TRANSPORTATION, PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

This study proposes a passenger assignment model for a frequency-based transit network, which takes into account not only the expected travel time but also the reliability of travel time as passengers' path choice criteria. The uncertainty of travel time in this study is derived from the variation of waiting time due to the service frequency and the possibility of failing to board the first train by the congestion. The measure of reliability, as well as the distribution of travel time, is calculated by considering Poisson distributed headway of each vehicle. Passengers are assumed to choose the path of the minimum generalised cost, which is defined as the weighted value of the expected travel time and the measure of travel time reliability. The model is formulated as a fixed point problem which represents the user equilibrium condition. The efficiency of the proposed model is demonstrated with a simple hypothetical network.

90. The Theory of Transit Assignment: Demand and Supply Phenomena

1. Gentile, Guido; Noekel, Klaus; Schmocker, Jan-Dirk; Trozzi, Valentina; Chandakas, Ektoras
2. MODELLING PUBLIC TRANSPORT PASSENGER FLOWS IN THE ERA OF INTELLIGENT TRANSPORT SYSTEMS: COST ACTION TU1004 (TRANSITS)

nan

91. A transit network assignment model based on congestion and preference

1. Niu, Huimin; Mao, Zhihong
2. 2007 IEEE INTERNATIONAL CONFERENCE ON AUTOMATION AND LOGISTICS, VOLS 1-6

This paper develops a new formulation for the problem of transit network assignment based on the congestion and preference. The multiple user groups are used to represent the travel preferences for the in-vehicle time, the waiting time and the number of transfers as traveling on the networks. A user equilibrium transit assignment model based on the fixed point problem is formulated in this paper.

Then, a heuristic solution algorithm applied to the method of successive averages is also proposed. A numerical example is finally used to illustrate the approach built in this paper.

92. A SCHEDULE-BASED CAPACITY RESTRAINED TRANSIT ASSIGNMENT MODEL FOR SYSTEM PLANNING IN THIS INFORMATION AGE - APPLICATION TO THE HONG KONG MASS TRANSIT RAILWAY NETWORK

1. Poon, M. H.; Tong, C. O.; Wong, S. C.

2. TRANSPORTATION IN THE INFORMATION AGE: PROCEEDINGS OF THE 7TH CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

Conventional transit assignment models are based on a restrictive assumption of non-congested steady state flow and average headway for each transit line during a specified period of analysis. With the advent of the information age, using this type of frequency-based models for operational planning is inadequate as they are not sensitive to the time varying nature of transit services and trip demands. This paper describes a capacity restrained trip assignment model for congested transit networks. The network formulation is dynamic and schedule-based and vehicles are assumed to operate to a pre-determined timetable. The path-loading algorithm adopts a time increment simulation method, which ensures that the capacity constraint of each vehicle is modeled correctly and passenger boarding at stations in First-in-first-out (FIFO). The minimum path algorithm and path-loading algorithm are applied iteratively by the method of successive averages until the network converges to a predictive dynamic user equilibrium. The Hong Kong Mass Transit Railway (MTR) network is used as a case study to validate the model and demonstrate its potential applications to the operational planning of a large-scale real railway system.

93. Modelling risk aversion using a disaggregate stochastic process model in congested transit networks

1. Seetharaman, Padma

2. PUBLIC TRANSPORT

Existing transit assignment models which either use equilibrium or stochastic processes assume full knowledge of the network. This assumption leads to an assignment process wherein passengers renounce their individual experiences to base their route choice on the collective experiences on each route. This seems unrealistic especially in a congested network in the absence of any external source of information. The fact that passengers failing to board a service of their choice experience a different level of reliability to a passenger being able to board the same needs to be acknowledged and a model, sensitive to the fact that reliability is an individual entity, needs to be explored. The stochastic process model proves to be one of the advantageous methods for countering the asymmetric non-separable nature of strict capacity constraint transit assignment, thereby making it a possible choice for modelling reliability. In the current paper such a 'Reliability based disaggregate stochastic process model (R-DSPM)' following the Markov principles with strict capacity constraints is proposed. The R-DSPM framework provides a stationary and ergodic process model. The model is implemented onto an example network and its sensitivity to various parameters is discussed along with a case study.

94. A dynamic stochastic model for evaluating congestion and crowding effects in transit systems

1. Cats, Oded; West, Jens; Eliasson, Jonas

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

One of the most common motivations for public transport investments is to reduce congestion and increase capacity. Public transport congestion leads to crowding discomfort, denied boardings and lower service reliability. However, transit assignment models and appraisal methodologies usually do not account for the dynamics of public transport congestion and crowding and thus potentially underestimate the related benefits. This study develops a method to capture the benefits of increased capacity by using a dynamic and stochastic transit assignment model. Using an agent-based public transport simulation model, we dynamically model the evolution of network reliability and on-board crowding. The model is embedded in a comprehensive framework for project appraisal. A case study of a metro extension that partially replaces an overloaded bus network in Stockholm demonstrates that congestion effects may account for a substantial share of the expected benefits. A cost-benefit analysis based on a conventional static model will miss more than a third of the benefits. This suggests that failure to represent dynamic congestion effects may substantially underestimate the benefits of projects, especially if they are primarily intended to increase capacity rather than to reduce travel times. (C) 2016 Elsevier Ltd. All rights reserved.

95. A NOTE ON INTRODUCING WALK OPTIONS IN STRATEGY TRANSIT ASSIGNMENT

1. Florian, Michael

2. TRANSPORTATION AND URBAN SUSTAINABILITY

This note develops an algorithm that applies a logit choice to transit strategies. It enriches the choices made in transit route choice by enlarging the options available at a stop between boarding a vehicle of a line which serves a stop and a short walk to another attractive line. The resulting algorithm is polynomial. A numerical example illustrates the method. While the model and the algorithm have been stated and developed for a binary choice between line and walk to line any number of walk links may be considered. The model may be easily generalized to multiple walk links.

96. TRANSIT ASSIGNMENT FOR CONGESTED PUBLIC TRANSPORT-SYSTEMS - AN EQUILIBRIUM-MODEL

1. DECEA, J; FERNANDEZ, E

2. TRANSPORTATION SCIENCE

We propose a new formulation for the assignment problem over congested transit networks. The congestion effects due to insufficient capacity of system elements (transit lines) are considered to be concentrated at transit stops. Waiting times on access links are therefore dependent on passenger flows. A special formulation of the transit network is used in order to model correctly the congestion effects. Finally, algorithms for solution are analyzed.

97. An equilibrium model for urban transit assignment based on game theory

1. Sun, Lian-Ju; Gao, Zi-You

2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

The urban public transport system is portrayed as a special commodity market where passenger is consumer, transit operator is producer and the special goods is the service for passenger's trip. The generalized Nash equilibrium game is applied to describe how passengers adjust their route choices

and trip modes. We present a market equilibrium model for urban public transport system as a series of mathematical programmings and equations, which is to describe both the competitions among different transit operators and the interactive influences among passengers. The proposed model can simultaneously predict how passengers choose their optimal routes and trip modes. An algorithm is designed to obtain the equilibrium solution. Finally, a simple numerical example is given and some conclusions are drawn. (c) 2006 Elsevier B.V. All rights reserved.

98. Transit assignment with strict capacity constraints in presence of countdown information

1. Padma, S.; Velmurugan, S.
2. 2018 10TH INTERNATIONAL CONFERENCE ON COMMUNICATION SYSTEMS & NETWORKS (COMSNETS)

The paper introduces a disaggregate learning process model to assess the line choice of transit passengers under the presence of countdown information at the transit stops. The model implements strict capacity constraints. The learning process follows the principle of finite memory for each individual passenger and instead of an equilibrium flow on each path; a stationary distribution of flow is obtained. The stationary behavior of the results is assessed using statistical techniques and the model is partially calibrated for a section of Delhi transit network. The learning process model accounts for the experienced travel times of the passenger and tries to assess the change in flows when the relative importance of experience vis-a-vis information changes. Policies such as a reliable inter arrival of transit services is evaluated.

99. A stochastic transit assignment model considering differences in passengers utility functions

1. Nielsen, OA
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

The paper presents a framework for public traffic assignment that builds on the probit-based model of Sheffi and Powell [Sheffi, Y., Powell, W.B., 1981. A comparison of stochastic and deterministic traffic assignment over congested networks. *Transportation Res. B.* 15 (1), 53-64; Sheffi, Y., Powell, W.B., 1982. An algorithm, for the equilibrium assignment problem with random link Times. *Networks* 12 (2), 191-207.]. Hereby, the problems with overlapping routes that occur in many public transport models can be avoided. The probit-based model with modifications similar to the principles in Nielsen [Nielsen, O.A., 1996. Do stochastic traffic assignment models consider differences in road users utility functions? Twentyfourth European Transport Forum (PTRC Annual Meeting). London, UK, Seminar M.] is used as a starting point. This makes it possible to describe passengers' different preferences towards different sub-modes and against transfers. This also considers dependencies of choices through chains of sub-modes. The simulation of perceived travel times is extended to describe differences in the distribution of travel- and waiting times for different sub-modes. Parallel lines are frequency aggregated in order to handle waiting times appropriately. Initial tests on a full-scale case show that the methodology can describe route choices in public transport very well. This is both due to the model's ability to describe overlapping routes and due to the many different coefficients, error components and distributions that make it possible to calibrate the model. In practice, the many parameters might also be the main weakness, since this complicates the calibration. At the end of the paper, proposals to coefficients are presented based on a Danish SP-analysis. This demonstrated the applicability of the method. (C) 2000 Elsevier Science Ltd. All rights reserved.

100. 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.

101. An online shortest path algorithm for reliable routing in schedule-based transit networks considering transfer failure probability

1. Khani, Alireza

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Most schedule-based transit assignment models assume deterministic vehicle arrival/departure times, in contrast to random vehicle arrival assumption in frequency-based models. This assumption simplifies user route choice behavior and fails to capture users' response to unreliable service. Moreover, the inherent inconvenience of transfers, primarily due to uncertain waiting time and failure probability, has always been a challenge in modeling transit networks, to the extent that determining an appropriate transfer penalty for heterogeneous user population is still a question when using planning models. This study aims to bridge the gap between frequency-based and schedule-based transit assignment models, and proposes a path algorithm in schedule-based transit networks with stochastic vehicle arrival times to model users' adaptive behavior in response to unreliable service. Path reliability is modeled by link failure probability, and an online shortest path algorithm is developed to find a routing policy with minimum expected travel time given preferred arrival time to destination. Complexity analyses and computational tests indicate that the model has potential for application in large-scale transit networks. Numerical tests verify that the model assigns passengers to more reliable paths with lower transfer rate without a need for a large transfer penalty. (C) 2019 Elsevier Ltd. All rights reserved.

102. Calibrating Rail Transit Assignment Models with Genetic Algorithm and Automated Fare Collection Data

1. Zhu, Wei; Hu, Hao; Huang, Zhaodong

2. COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

Recently, automated fare collection (AFC) systems using smart card technology have become the main method for collecting urban rail transit (URT) fares in many cities around the world. Transaction data obtained through these AFC systems contain a large amount of archived information including how passengers use the URT system, and thus can be used in calibrating assignment models for precise passenger flow calculation. We present a methodology for calibrating URT assignment models using AFC data. The calibration approach uses a genetic algorithm-based framework with nonparametric statistical techniques. Three initial numerical tests show that the proposed approach finds more reasonable solutions than traditional approaches for the calibrated parameters. Furthermore, after calibration by the proposed approach, the existing assignment model delivers more accurate calculations of passenger flows in the network.

103. The effect of crowding on public transit user travel behavior in a large-scale public transportation system through modeling daily variations

1. Yook, Donghyung; Heaslip, Kevin

2. TRANSPORTATION PLANNING AND TECHNOLOGY

In this paper, the crowding effect in a transit vehicle is modeled in a time-expanded network that considers the daily variation in passenger flows. The study models the daily variation of in-vehicle crowding in a real large-scale transit system. A transit assignment for this real network is modeled and implemented by constructing a crowding cost function that follows the valuation of crowding and by using the reliable shortest path finding method. The direct application of the crowding model to a real network for the Utah Transit Authority indicates that crowd modeling with multi-user classes could influence public transportation system planning and affect the revenues of transit agencies. Moreover, the addition of the disutility factor, crowding, does not always appear to cause an increase in disutility for transit users.

104. Fundamental diagram of urban rail transit considering train-passenger interaction

1. Seo, Toru; Wada, Kentaro; Fukuda, Daisuke

2. TRANSPORTATION

Urban rail transit often operates with high service frequencies to serve heavy passenger demand during rush hours. Such operations can be delayed by two types of congestion: train congestion and passenger congestion, both of which interact with each other. This delay is problematic for many transit systems, since it can be amplified due to the interaction. However, there are no tractable models describing them; and it makes difficult to analyze management strategies of congested transit systems in general and tractable ways. To fill this gap, this article proposes simple yet physical and dynamic model of urban rail transit. First, a fundamental diagram of transit system (i.e., theoretical relation among train-flow, train-density, and passenger-flow) is analytically derived considering the aforementioned physical interaction. Then, a macroscopic model of transit system for dynamic transit assignment is developed based on the fundamental diagram. Finally, accuracy of the macroscopic model is investigated by comparing to microscopic simulation. The proposed models would be useful for mathematical analysis on management strategies of urban rail transit systems, such as optimal dynamic pricing for travel demand management.

105. Validation of a schedule-based capacity restraint transit assignment model for a large-scale network

1. Poon, MH; Tong, CO; Wong, SC
2. JOURNAL OF ADVANCED TRANSPORTATION

This paper describes the application of a capacity restraint trip assignment algorithm to a real, large-scale transit network and the validation of the results. Unlike the conventional frequency-based approach, the network formulation of the proposed model is dynamic and schedule-based. Transit vehicles are assumed to operate to a set of pre-determined schedules. Passengers are assumed to select paths based on a generalized cost function including in-vehicle and out-of-vehicle time and line change penalty. The time-varying passenger demand is loaded onto the network by a time increment simulation method, which ensures that the capacity restraint of each vehicle during passenger boarding is strictly observed. The optimal-path and path-loading algorithms are applied iteratively by the method of successive averages until the network converges to the predictive dynamic user equilibrium. The Hong Kong Mass Transit Railway network is used to validate the model results. The potential applications of the model are also discussed.

106. Optimal sectional fare and frequency settings for transit networks with elastic demand

1. Sun, S.; Szeto, W. Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Sectional fares have been used in transit services in practice but are rarely examined analytically and compared with flat and distance-based fares, especially under the considerations of path choice, elastic demand, service frequency, and profitability. This paper proposes a bilevel programming model to jointly determine the fare and frequency setting to maximize transit operator's profit. The preceding three fare structures can be incorporated into the bilevel model. To consider the path choice and elastic demand in the bilevel model, the existing approach-based stochastic user equilibrium transit assignment model for the fixed demand was extended to the elastic demand case and the resultant model was used in the lower level model. To solve the bilevel model, the sensitivity-based descent search method that takes into account the approach-based formulation for the elastic demand transit assignment is proposed, in which the approach-based formulation was solved by the cost-averaging self-regulated averaging method. Numerical studies and mathematical analyses were performed to examine the model properties and compare the three fare structures. The result of the Tin Shui Wai network instance is also provided to illustrate the performance of the solution method. It is proven that when all passengers' destinations are located at transit terminals, the sectional fare structure is always better than the other two fare structures in terms of profitability. For more general networks, the sectional fare structure is always better than the flat fare structure, but the choice between sectional and distance-based fare structures depends on the geometry of the network (e.g., the route structure and the distance between stops), the demand distribution, and the maximum allowable fares. It is also proven that the optimal profit (total vehicle mileage) is strictly monotonically decreasing (monotonically decreasing) with respect to the unit operating cost. Moreover, it is proven that the lower level approach-based assignment problem with elastic demand has exactly one solution. However, the bi-level problem can have multiple optimal solutions. Interestingly, it is found that from the operator's profitability point of view, providing better information to the passengers may not be good. (C) 2019 Elsevier Ltd. All rights reserved.

107. Advanced public transport and intelligent transport systems: new modelling challenges

1. Nuzzolo, Agostino; Comi, Antonio

2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

Transit system big data' collecting and processing, and bidirectional communication between transit travellers and information centres are emerging as two factors that enhance the tools supporting short-term forecasting of network status for transit operations control and for traveller information. However, the current methodologies applied in these tools do not seem to have reached the level of research in the field of transit network modelling. Therefore, several methodological issues connected to the development of such tools are analysed in this paper. These issues concern application and development of real-time on-board load short-term forecasting methods, real-time best path advice, real-time transit assignment modelling, individual path choice modelling, and real-time updating and upgrading of demand and supply model parameters.

108. Assessing the benefits of integrated en-route transit information systems and time-varying transit pricing systems in a congested transit network

1. Ren, Hualing; Gao, Ziyu; Lam, William H. K.; Long, Jiancheng

2. TRANSPORTATION PLANNING AND TECHNOLOGY

This paper proposes a model for assessing the effects of the integrated implementation of en-route transit information systems (ETIS) and time-varying transit pricing systems (TTPS). The proposed model reveals the interaction between ETIS and TTPS, and the potential benefit of the joint implementation. There are two classes of passengers: those equipped and those unequipped with ETIS. It is assumed that unequipped passengers make their travel choices according to stochastic dynamic user optimal principles, with equipped passengers having a lower perception variation of travel cost due to the availability of better information. A bi-level program is formulated to model the integrated effects on passengers' departure time choice behavior, route choice behavior, transit network performance, and transit operators' revenue. The lower level is a multi-class stochastic dynamic transit assignment model. The combined system total cost and operators' benefits under varied transit conditions are investigated with a numerical example.

109. SAfE transport: wearing face masks significantly reduces the spread of COVID-19 on trains

1. Grzybowska, Hanna; Hickson, R., I; Bhandari, Bishal; Cai, Chen; Towke, Michael; Itzstein, Benjamin; Jurdak, Raja; Liebig, Jessica; Najeebullah, Kamran; Plan, Adrian; El Shoghri, Ahmad; Paini, Dean

2. BMC INFECTIOUS DISEASES

COVID-19 has had a substantial impact globally. It spreads readily, particularly in enclosed and crowded spaces, such as public transport carriages, yet there are limited studies on how this risk can be reduced. We developed a tool for exploring the potential impacts of mitigation strategies on public transport networks, called the Systems Analytics for Epidemiology in Transport (SAfE Transport). SAfE Transport combines an agent-based transit assignment model, a community-wide transmission model, and a transit disease spread model to support strategic and operational decision-making. For this simulated COVID-19 case study, the transit disease spread model incorporates both direct (person-to-person) and fomite (person-to-surface-to-person) transmission modes. We determine the probable impact of wearing face masks on trains over a seven day simulation horizon, showing substantial and statistically significant reductions in new cases when passenger mask wearing proportions are greater than 80%. The higher the level of mask coverage, the greater the reduction in the number of new

infections. Also, the higher levels of mask coverage result in an earlier reduction in disease spread risk. These results can be used by decision makers to guide policy on face mask use for public transport networks.

110. The Railway Rapid Transit frequency setting problem with speed-dependent operation costs

1. Canca, David; Luis Andrade-Pineda, Jose; De los Santos, Alicia; Calle, Marcos
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

In this paper we deal with the problem of determining the best set of frequencies in a Railway Rapid Transit network considering convex non-linear variable operation costs at segments. The operation cost at each track will depend on the train model characteristics operating each line, the passenger load on trains and the average train speed. Given the network topology and the passenger mobility patterns, we propose a methodology to determine the best regular timetable, taking into account both, users' and service provider points of view. Since the frequency setting and the passengers assignment are intertwined problems, the proposed procedure solves a succession of interrelated transit assignments and frequency setting models. At each iteration, given a transit assignment, the resultant frequency setting problem turns into a Mixed Integer Non-Linear model which is solved to optimality in a sequential way, both considering the different train models and the passenger load on trains. The proposed methodology is illustrated on a real-size scenario. (C) 2018 Elsevier Ltd. All rights reserved.

111. Calibration of Rail Transit Assignment Model with Automated Fare Collection Data and a Parallel Genetic Algorithm

1. Zhu, Wei; Xu, Ruihua; Jiang, Yue-Ping
2. TRANSPORTATION RESEARCH RECORD

In recent years, cities around the world have begun to use automated fare collection (AFC) systems with smart card technologies as the main method of collecting urban rail transit (URT) fares. Transaction data obtained through these AFC systems contain a large amount of archived information about how passengers use the URT system. These data can be used to calibrate assignment models for precise passenger flow calculations. However, this calibration typically is a computationally intensive problem because of multiroute searches, iteration strategies, and especially massive AFC data sets. This paper proposes a methodology for calibrating URT assignment models with AFC data and a parallel genetic algorithm. The calibration approach uses a framework based on a parallel genetic algorithm with nonparametric statistical techniques, which calibrate assignment model parameters by comparing observed and calculated travel time distributions. In initial case studies on the URT network in Beijing, the proposed approach found reasonable solutions for the calibrated parameters.

112. Reliability-based equitable transit frequency design

1. Jiang, Yu
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

Fairness is an important criterion for achieving sustainable urban development. While most existing studies focus on accessing or evaluating the fairness condition of a given transit network, this study explicitly incorporates fairness as an objective in the planning step. A multi-objective bilevel programming model is developed where the lower level problem is the reliability-based transit

assignment problem and the upper level problem is to determine optimal frequency settings to simultaneously minimise the total effective travel cost and maximise the network fairness condition. A multi-objective Artificial Bee Colony algorithm is developed to solve the bilevel model. Numerical studies find that: (1) increasing the frequency may not improve the fairness condition; (2) there is a tradeoff between the two objectives (3) the effect of passengers' risk aversion attitude on the fairness measurement depends on the frequency setting; it could either amplify the fairness measurements or have no impact.

113. A Frequency Based Transit Assignment Model that Considers Online Information and Strict Capacity Constraints (vol 9, 100005, 2020)

1. Olikar, Nurit; Bekhor, Shlomo
2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

nan

114. On seat capacity in traffic assignment to a transit network

1. Leurent, Fabien
2. JOURNAL OF ADVANCED TRANSPORTATION

Seating or standing make distinct on-board states to a transit rider, yielding distinct discomfort costs, with potential influence on the passenger route choice onto the transit network. The paper provides a transit assignment model that captures the seating capacity and its occupancy along any transit route. The main assumptions pertain to: the seat capacity by service route, selfish user behaviour, a seat allocation process with priority rules among the riders, according to their prior state either on-board or at boarding. To each transit leg from access to egress station is associated a set of service modes, among which the riders are assigned in a probabilistic way, conditionally on their priority status and the ratio between the available capacity and the flow of them. Thus the leg cost is a random variable, with mean value to be included in the trip disutility. Computationally efficient algorithms are provided for, respectively, loading the leg flows and evaluating the leg costs along a transit line. At the network level, a hyperpath formulation is provided for supply-demand equilibrium, together with a property of existence and an method of successive averages equilibration algorithm. It is shown that multiple equilibria may arise. Copyright (C) 2010 John Wiley & Sons, Ltd.

115. Integrated framework of departure time choice, mode choice, and route assignment for large-scale networks

1. Kamel, Islam; Hasnine, Md Sami; Shalaby, Amer; Habib, Khandker Nurul; Abdulhai, Baher
2. CASE STUDIES ON TRANSPORT POLICY

This paper presents a large-scale integrated modelling framework that can capture the relationships between travel mode choice, departure time choice and route choices simultaneously. Conventional transportation models have typically been applied to small scale networks to avoid the complexity of the large-scale simulation. While there are different approaches and strategies that researchers have presented to tackle the transportation congestion challenges, such strategies need to be accurately evaluated at the full system scale before implementation. The proposed framework integrates an econometric model for travel mode and departure time choice with a simulation-based dynamic traffic and transit assignment model. It addresses the interactions between the traffic and transit networks in

addition to their interactions with the mode and departure time choice model. A case study of the proposed modelling framework is presented in this paper, where the effects of replacing the current flat transit fare used in the City of Toronto with a time-based transit fare structure are captured. It is found that an increase in the fare during the middle of the peak results in a reduction in transit vehicles crowdedness. The scenario analysis also shows that 1.85% of transit users will shift their departure time from the (congested) middle period of the peak to the (less costly) shoulders of the peak, whilst 2.6% of transit users optout of using transit in favour of either driving or accompanying another driver.

116. Evaluation of an existing bus network using a transit network optimisation model: a case study of the Hiroshima City Bus network

1. Shimamoto, Hiroshi; Murayama, Naoki; Fujiwara, Akimasa; Zhang, Junyi

2. TRANSPORTATION

This study evaluates an existing bus network from the perspectives of passengers, operators, and overall system efficiency using the output of a previously developed transportation network optimisation model. This model is formulated as a bi-level optimisation problem with a transit assignment model as the lower problem. The upper problem is also formulated as bi-level optimisation problem to minimise costs for both passengers and operators, making it possible to evaluate the effects of reducing operator cost against passenger cost. A case study based on demand data for Hiroshima City confirms that the current bus network is close to the Pareto front, if the total costs to both passengers and operators are adopted as objective functions. However, the sensitivity analysis with regard to the OD pattern fluctuation indicates that passenger and operator costs in the current network are not always close to the Pareto front. Finally, the results suggests that, regardless of OD pattern fluctuation, reducing operator costs will increase passenger cost and increase inequity in service levels among passengers.

117. A Trip-Chain Based Combined Mode and Route Choice Network Equilibrium Model Considering Common Lines Problem in Transit Assignment Model

1. Higuchi, Takashi; Shimamoto, Hiroshi; Uno, Nobuhiro; Shiomi, Yasuhiro

2. STATE OF THE ART IN THE EUROPEAN QUANTITATIVE ORIENTED TRANSPORTATION AND LOGISTICS RESEARCH, 2011: 14TH EURO WORKING GROUP ON TRANSPORTATION & 26TH MINI EURO CONFERENCE & 1ST EUROPEAN SCIENTIFIC CONFERENCE ON AIR TRANSPORT

This paper proposes new type of combined mode and route choice network equilibrium model where the travellers are assumed to choose their mode considering whole of their trip-chain and the common lines problem is considered in the public transportation assignment. In the proposed model, the nested-logit type of mode and route choice structure is assumed for travellers' mode and route choice. The proposed model is formulated with the Variational Inequality Problem and the relaxation method is applied to solve the proposed model. Finally, the proposed model is applied to a small network. (C) 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the Organizing Committee.

118. A strategy-based recursive path choice model for public transit smart card data

1. Nassir, Neema; Hickman, Mark; Ma, Zhen-Liang

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

A recursive logit model is proposed for path choice modeling with transit smart card data in higher-frequency bus and rail services. In such circumstances, it is commonly assumed that passengers may arrive randomly to a stop and may behave according to a strategy; such a strategy is associated with a so-called attractive set of routes: a passenger selects a set of routes departing from the stop, and will board the next vehicle to depart from among that set of routes. We extend the conventional notion of attractive sets by introducing a measure of attractiveness that allows for randomness in the choice of attractive routes. The proposed model uses a link-based (recursive, or sequential choice) formulation, rather than a path-based formulation, which has the advantage of including all path alternatives without the need for path set enumeration. The recursive formulation is also very suitable for smart card data because it allows model calibration with incomplete path choice observations. The link-based approach was originally advocated by Nguyen et al. (1988) in the strategy-based transit assignment context, but without investigating methods for model calibration or empirical analysis. Recently, Fosgerau et al. (2013) and Mai et al. (2015) have presented methods to empirically estimate traffic path choice models using a link-based formulation. Our framework builds off these previous works to formulate and estimate a strategy-based path choice model with smart card data. The proposed model is tested with a 6 months extract from the smart card transactions in Brisbane, Australia, for two popular origin-destination pairs with diverse path alternatives. (C) 2018 Elsevier Ltd. All rights reserved.

119. Evaluating critical lines and stations considering the impact of the consequence using transit assignment model -: Case study of London's underground network

1. Shimamoto, Hiroshi; Kurauchi, Fumitaka; Schmocker, Jan-Dirk; Bell, Michael G. H.
2. JOURNAL OF ADVANCED TRANSPORTATION

As the problem of full transit vehicles is encountered daily by passengers in most of the big cities, previous research evaluated the consequence of overcrowding in terms of on-board crowding and passengers not being able to board with full vehicles. The impact of overcrowding in the real world is, however, not necessarily proportional to these numbers. This paper attempts to specify the critical lines and stations of a network by considering the number of passengers failing to board and attempting to evaluate its impact on service quality and safety risks. The hypothesis is that larger stations with wider platforms can often cope better with overcrowding than smaller stations. Therefore a station size dependent satisfaction function is proposed, which takes values from 0 to 1. The method is applied to London's underground network with a number of scenarios which show critical stations in the network if delays occur.

120. An inverse bilevel equilibrium problem for public transport demand estimation

1. Orlando, Victoria M.; Baquela, Enrique G.; Bhourri, Neila; Lotito, Pablo A.
2. IFAC PAPERSONLINE

We consider the problem of demand estimation for public transport networks. Given an origin-destination matrix representing the public transport demand, the distribution of flow among different lines can be obtained assuming that it corresponds to a certain equilibrium characterized by an optimization problem. The knowledge of the origin-destination matrix is expensive and sometimes unaffordable in practice. Traditionally, it is estimated using statistical or econometrical considerations. In this work, we explore the estimation through the numerical solution of a bilevel optimization problem. One disadvantage of this formulation is the difficulty of obtaining descent directions, therefore we proposed a derivative-free method for the resolution of the optimization problem. The

method is firstly tested on small networks using a derivative-free optimization method and then, using an approach based on simulation. This simulation-optimization methodology showed as good results as analytical modeling, opening the door to handle bigger networks where analytical computation is hard to accomplish. Copyright (C) 2021 The Authors.

121. Stochastic assignment to high frequency transit networks: models, algorithms, and applications with different perceived cost distributions

1. Cantarella, GE; Vitetta, A

2. MATHEMATICAL METHODS ON OPTIMIZATION IN TRANSPORTATION SYSTEMS

In urban areas transportation demand is commonly served both by private cars and mass transit systems (bus, tram, metro, etc.), which are usually based on a network of partially competing and overlapping lines. Therefore, user pre-trip path choice behaviour in transit systems refers to overall strategies that specify which line will be boarded at each bus stop (more generally how the user will behave at diversion nodes). The topology of user strategies are effectively modelled by hyperpaths (introduced by Nguyen and Pallottino, 1988). The pre-trip choice among hyperpaths (say strategies) is currently simulated through a deterministic choice model. This assumption leads to deterministic network loading or user equilibrium assignment for uncongested or congested network respectively. In this paper the pre-trip choice among hyperpaths is simulated through probabilistic choice models derived from random utility theory. Resulting stochastic network loading and user equilibrium models are analysed as well as solution algorithms. Results of an application to a test system and a real one are also reported, using different perceived cost distribution.

122. Dynamic user equilibrium in public transport networks with passenger congestion and hyperpaths

1. Trozzi, Valentina; Gentile, Guido; Bell, Michael G. H.; Kaparias, Ioannis

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper presents a dynamic user equilibrium for bus networks where recurrent overcrowding results in queues at stops. The route-choice model embedded in the dynamic assignment explicitly considers common lines and strategies with alternative routes. As such, the shortest hyperpath problem is extended to a dynamic scenario with capacity constraints where the diversion probabilities depend on the time at which the stop is reached and on the expected congestion level at that time. In order to reproduce congestion for all the lines sharing a stop, the Bottleneck Queue Model with time-varying exit capacity, introduced in Meschini et al. (2007), is extended. The above is applied to separate queues for each line in order to satisfy the First-In-First-Out principle within every attractive set, while allowing overtaking among passengers with different attractive sets but queuing single file. The application of the proposed model to a small example network clearly reproduces the formation and dispersion of passenger queues due to capacity constraints and thus motivates the implementation of the methodology on a real-size network case as the next step for future research. (C) 2013 Elsevier Ltd. All rights reserved.

123. Dynamic User Equilibrium in Public Transport Networks with Passenger Congestion and Hyperpaths

1. Trozzi, Valentina; Gentile, Guido; Bell, Michael; Kaparias, Ioannis

2. 20TH INTERNATIONAL SYMPOSIUM ON TRANSPORTATION AND TRAFFIC THEORY (ISTTT 2013)

This paper presents a Dynamic User Equilibrium for bus networks where recurrent overcrowding results in queues at stops. The route choice model embedded in the dynamic assignment explicitly considers common lines and strategies with alternative routes. As such, the shortest hyperpath problem is extended to a dynamic scenario with capacity constraints where the diversion probabilities depend on the time the stop is reached and on the expected congestion level at that time. In order to reproduce congestion for all the lines sharing a stop, the Bottleneck Queue model with time-varying exit capacity, introduced in Meschini et al. (2007), is extended. The above is applied to separate queues for each line in order to satisfy the First-In-First-Out principle within every attractive set, while allowing overtaking among passengers having different attractive sets but queuing single file. (C) 2013 The Authors. Published by Elsevier Ltd.

124. A frequency-based assignment model for congested transit networks with strict capacity constraints: characterization and computation of equilibria

1. Cepeda, M; Cominetti, R; Florian, M
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper concerns a frequency-based route choice model for congested transit networks, which takes into account the consequences of congestion on the predicted flows as well as on the expected waiting and travel times. The paper builds on the results presented in Correa [Correa, J., 1999. Asignacion de flujos de pasajeros en redes de transporte publico congestionadas. Engineering thesis, U. de Chile, Santiago] and Cominetti and Correa [Cominetti, R., Correa, J., 2001. Common-lines and passenger assignment in congested transit networks. Transportation Science 35(3), 250-267], extending these to obtain a new characterization of the equilibria which allows us to formulate an equivalent optimization problem in terms of a computable gap function that vanishes at equilibrium. This new model formulation can deal with flow dependent travel times and is a generalization of the previously known strategy (hyperpath) based transit network equilibrium models. The approach leads to an algorithm which has been applied successfully on large scale networks. Computational results for transit networks originating from practice demonstrate the applicability of the proposed approach. (c) 2005 Elsevier Ltd. All rights reserved.

125. 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. CANADIAN JOURNAL OF CIVIL ENGINEERING

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.

126. Dynamic assignment model of trains and users on a congested urban-rail line

1. Poulhes, Alexis

2. JOURNAL OF RAIL TRANSPORT PLANNING & MANAGEMENT

For the management and planning of urban rail lines, operators can draw upon tools that use train circulation models as well as passenger assignment models. However, these two kinds of simulation models are independent. They do not interact as they do in reality. Yet on certain highly congested lines, high train frequency and large passenger volumes can turn a small incident into a delay on the entire line. Our research presents an integrated model for the simulation of a fixed block urban rail line in interaction with passenger assignment. This operational model introduces new management strategies or rolling stock feature solutions to improve the quality of service on the line. A discrete-event approach simulates the progress of the runs on the line, and the representation of the passengers by origin-destination flow per time step makes it possible to effectively simulate lines with large flows. An application to Line 13 of the Paris metro illustrates the model on a real case of congestion. Sensitivity analyses on the level of demand as well as on service characteristics demonstrate the utility of this integrated approach.

127. Demand responsive urban public transport system design: Methodology and application

1. Enrique Fernandez L, J.; de Cea Ch, Joaquin; Henry Malbran, R.

2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

In this paper, we present a methodology for solving the Public Transport Network Design Problem (PTNDP) and describe its application in the context of the Design Study developed in order to propose a new structure for the transit system of the city of Santiago, Chile. Firstly, we briefly define the PTNDP as a multilevel programming problem and discuss the solution method implemented. Then, the application of this methodology to the Santiago transit system is presented, and the main results obtained are analyzed. The new restructured system, based on a hierarchy of specialized services that complement and coordinate their operations and using an integrated fare scheme, is compared with an optimized version (optimal frequencies) of the current one, a set of direct services, mainly based on the operation of independent itineraries, without fare integration. The most important conclusions are the following: (a) the private operating costs and the social costs of the restructured system, using higher standard buses, are considerably lower than the costs of the current system; (b) these cost reductions allow government authorities to introduce an important number of modernizing measures without subsidies and fare increases. (C) 2008 Elsevier Ltd. All rights reserved.

128. Congestion Pricing for Schedule-Based Transit Networks

1. Hamdouch, Younes; Lawphongpanich, Siriphong

2. TRANSPORTATION SCIENCE

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.

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

1. Liu, Zhiyuan; Meng, Qiang
2. INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE

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.

130. Integrated Mode Choice and Dynamic Traveler Assignment in Multimodal Transit Networks Mathematical Formulation, Solution Procedure, and Large-Scale Application

1. Verbas, I. Omer; Mahmassani, Hani S.; Hyland, Michael F.; Halat, Hooram
2. TRANSPORTATION RESEARCH RECORD

This paper introduces an integrated mode choice-multimodal transit assignment model and solution procedure intended for large-scale urban applications. The cross-nested logit mode choice model assigns travelers to car, transit, or park-and-ride. The dynamic multimodal transit assignment-simulation model determines minimum hyperpaths and assigns and simulates transit and park-and-ride travelers iteratively until the network approaches a state of equilibrium. After a given number of iterations, the updated transit network travel times are fed into the mode choice model and the model reassigns travelers to transit, car, or park-and-ride. The outer feedback loop between the mode choice model and the transit assignment model continues until the mode probabilities for each traveler do not change between iterations. A unique contribution of the method presented in this paper is that it reaches mode choice convergence with the use of disaggregate agents (travelers) instead of aggregate modal flows at the origin-destination level. The integrated model is successfully implemented on the Chicago Transit Agency's bus and train network in Illinois. Different procedures for reaching convergence are tested; the results suggest that a gap-based formulation is more efficient than the method of successive averages.

131. Hyperpath-based algorithms for the transit equilibrium assignment problem

1. Xu, Zhandong; Xie, Jun; Liu, Xiaobo; Nie, Yu (Marco)
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

The transit equilibrium assignment problem (TEAP) aims to predict the distributions of passenger flows on lines or line segments in a transit network. Compared to the traffic assignment problem (TAP) for

highway networks, the TEAP is much less studied, especially in terms of solution algorithms. This paper proposes two Newton-type hyperpath-based algorithms for a frequency based TEAP formulation that considers both the congestion effect related to crowding and the queuing effect related to boarding. These newly developed algorithms, as well as two benchmark algorithms from the literature, are tested and compared on a number of transit networks, including two constructed using real-world data. The results show the proposed hyperpath-based algorithms significantly outperform the benchmark algorithms in large networks.

132. USING POTENTIAL ACCESSIBILITY MEASURE FOR URBAN PUBLIC TRANSPORTATION PLANNING: A CASE STUDY OF DENIZLI, TURKEY

1. Gulhan, Gorkem; Ceylan, Huseyin; Baskan, Ozgur; Ceylan, Halim

2. PROMET-TRAFFIC & TRANSPORTATION

Policy makers and planners evaluate the implementation of the urban public transport (UPT) planning studies in terms of some objective measures such as load factor, mean volume per trip, capacity usage ratio and total capacity. In some cases, improving these measures may lead an unforeseen decrease on accessibility to the opportunities in terms of UPT users. Thus, this study aims to evaluate Potential Accessibility (PA) as an efficiency measure in decision stage of UPT planning. It widely depends on fieldwork, surveys, data inventories and existing plans. In this context, a comprehensive UPT planning has been carried out through VISUM traffic simulation software by taking the PA into account, and a four-step UPT planning procedure has been proposed. The results showed that PA may alternatively be used as an evaluation instrument in decision stage of UPT planning while the objective measures are insufficient to represent the effectiveness of alternative scenarios.

133. The transit bottleneck model

1. Leurent, Fabien; Chandakas, Ektoras

2. PROCEEDINGS OF EWGT 2012 - 15TH MEETING OF THE EURO WORKING GROUP ON TRANSPORTATION

The paper addresses the issue of passenger waiting and being stored at a station platform, from which point they plan to board transit services towards egress stations. Each transit service has a specific set of downstream egress stations and is operated at given frequency using homogeneous vehicles of limited available capacity. The model yields individual waiting time by egress station and the assignment of vehicle capacity to the flows by egress station. Two cases are distinguished, unsaturated versus saturated. The unsaturated case is addressed by standard line combination, where service frequency is added up among the routes that service a given egress station. The saturated case is addressed by making explicit the average number of passengers waiting on platform for a given egress station. From these passenger stocks is derived the individual probability to board a vehicle of limited capacity that service a given route hence a given subset of egress stations. Waiting passengers are assumed to be mingling on the origin platform. The subset of routes that service a given egress station, their vehicle capacities and the boarding probabilities induce a line capacity for that destination: to this is faced the passenger flow demanded during the assignment period, in a bottleneck model that yields an average waiting time per passenger. The vector of passenger stocks by egress station is shown to satisfy a fixed point problem. The existence and uniqueness of the solution are demonstrated on the basis of an equivalent, convex minimization program. A Newton-Raphson

algorithm is recommended for computation and demonstrated in an instance of application. (C) 2012
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134. Including passengers' response to crowding in the Dutch national train passenger assignment model

1. Pel, Adam J.; Bel, Nick H.; Pieters, Marits
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

Transit passengers' response to crowded conditions has been studied empirically, yet is limitedly included in transport models currently used in the design of policy and infrastructure investments. This has consequences for the practical applicability of these models in studies on, for instance, timetabling, train capacity management strategies, project appraisal, and passenger satisfaction. Here we propose four methods to include the effect of crowding, based on existing studies on passengers' perception and response as well as often-used crowding indicators. These four alternative methods are implemented in the train passenger assignment procedure of the Dutch national transport model, and evaluated with respect to their impacts on the model results for the Dutch railway network. The four methods relate to four different ways in which an additive trip penalty and/or time-multiplier can be incorporated in the train utility function for different travel purposes, to capture the disutility of crowding as measured by the load factor. The analyses of the test case favor the hybrid method using both a boarding penalty (capturing seat availability upon boarding) and a time-multiplier (capturing physical comfort and safety throughout the trip). This method produces consistent results, while the additional computational effort that it imposes is acceptable. Further empirical underpinning is needed to conclusively show which of these methods best captures passengers' response behavior quantitatively (for different travel purposes and conditions). (C) 2014 Elsevier Ltd. All rights reserved.

135. A Transit Bottleneck Model for Waiting Passengers and its Implications for Traffic Assignment

1. Leurent, Fabien; Chandakas, Ektoras; Christoforou, Zoi
2. 2015 INTERNATIONAL CONFERENCE ON MODELS AND TECHNOLOGIES FOR INTELLIGENT TRANSPORTATION SYSTEMS (MT-ITS)

The paper addresses the issue of passenger waiting at a station platform, from which they plan to board transit services towards egress stations. Each transit service has a specific set of downstream egress stations and is operated at given frequency using homogeneous vehicles of limited available capacity. We propose a static model that yields passenger stocks on the platform and individual waiting times by egress station, as well as the assignment of vehicle capacity to the flows by egress station. Two cases are considered; unsaturated versus saturated. The unsaturated case is addressed by standard line combination, where service frequency is added up among the routes that serve a given egress station. The saturated case is addressed by making explicit the average number of passengers waiting on platform for a given egress station. From these passenger stocks, we deduce the individual probability to board a vehicle of limited capacity that serves a given route (hence a given subset of egress stations). Waiting passengers are assumed to be mingling on the origin platform. The subset of routes that serve a given egress station, their vehicle capacities along with the associated boarding probabilities give a line capacity by destination. The bottleneck model confronts this capacity to demand during the assignment period and provides both the stock of waiting passengers and an

average waiting time per passenger. The vector of passenger stocks by egress station is shown to satisfy a fixed point problem. The existence of a solution is demonstrated.

136. Assigning Passenger Flows on a Metro Network Based on Automatic Fare Collection Data and Timetable

1. Hong, Ling; Li, Wei; Zhu, Wei
2. DISCRETE DYNAMICS IN NATURE AND SOCIETY

Assigning passenger flows on a metro network plays an important role in passenger flow analysis that is the foundation of metro operation. Traditional transit assignment models are becoming increasingly complex and inefficient. These models may even not be valid in case of sudden changes in the timetable or disruptions in the metro system. We propose a methodology for assigning passenger flows on a metro network based on automatic fare collection (AFC) data and realized timetable. We find that the routes connecting a given origin and destination (O-D) pair are related to their observed travel times (OTTs) especially their pure travel times (PTTs) abstracted from AFC data combined with the realized timetable. A novel clustering algorithm is used to cluster trips between a given O-D pair based on PTTs/OTTs and complete the assignment. An initial application to categorical O-D pairs on the Shanghai metro system, which is one of the largest systems in the world, shows that the proposed methodology works well. Accompanying the initial application, an interesting approach is also provided for determining the theoretical maximum accuracy of the new assignment model.

137. Modeling intermodal networks with public transport and vehicle sharing systems

1. Friedrich, Markus; Noekel, Klaus
2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

This paper extends a schedule-based transit assignment model to integrate vehicle sharing systems (VSS) with or without fixed stations permitting oneway rentals. It is assumed that travelers receive information through mobile internet on vehicle location and availability and that they can use a real-time booking service. The proposed model extends the functionality of a scheduled-based transit assignment in two ways: (1) It generates intermodal route choice sets combining transit and non-transit trip legs. This functionality enables an accessibility analysis to identify od-pairs benefiting from VSS. (2) It distributes a given travel demand on the route choice set considering capacity constraints of VSS. This functionality can be applied for an impact analysis of a proposed VSS.

138. A schedule-based dynamic transit network model - Recent advances and prospective future research

1. Tong, CO; Wong, SC; Poon, MH; Tan, MC
2. JOURNAL OF ADVANCED TRANSPORTATION

Using the schedule-based approach, in which scheduled timetables are used to describe the movement of vehicles, a dynamic transit assignment model is formulated. Passengers are assumed to travel on a path with minimum generalized cost that consists of four components: in-vehicle time; waiting time; walking time; and a time penalty for each line change. A specially developed branch and bound algorithm is used to generate the time-dependent minimum path. The assignment procedure is conducted over a period in which both passenger demand and train headway are varying. This paper

presents an overview of the research that has been carried out by the authors to develop the schedule-based transit assignment model, and offers perspectives for future research.

139. An Optimal Transit Fare and Frequency Design Model with Equity Impact Constraints

1. Huang, Di; Wang, Zelin; Zhang, Honggang; Dong, Run; Liu, Zhiyuan
2. JOURNAL OF TRANSPORTATION ENGINEERING PART A-SYSTEMS

Distance-based fares have been applied widely in practice using automatic fare collection technology. This paper proposes an optimization model for the distance-based transit fare structure. A bilevel model was formulated to obtain the optimal fare functions with the aim of minimizing the Gini coefficient of the entire transit system. Passengers' travel behavior is modeled by a stochastic transit assignment problem in the lower level. Considering the inherent complexity of the bilevel model, a heuristic algorithm, namely the artificial bee colony algorithm, is applied, which is incorporated with a method of successive averages to solve the transit assignment subproblem. The results show that the Euclidean distance-based fare has better performance in terms of social equity, but it is less equitable for passengers with middistance trips.

140. Transit vehicles' headway distribution and service irregularity

1. Bellei, Giuseppe; Gkoumas, Konstantinos
2. PUBLIC TRANSPORT

Pairing, or bunching, of vehicles on a public transportation line influences the adaptive choice at stops due to the random headways and waiting times it determines. In order to ensure consistency with the characteristics of service perturbations, as represented by a transit operation model, it is important to identify the headway distributions representing service perturbations. A stochastic simulation model is developed for a one-way transit line, which accounts for several service characteristics (dwell time at stops, capacity constraint and arrivals during the dwell time). Samples of headways at the main stops are utilized to build histograms of the headway's frequencies by their length, which allow to identify the functional forms and parameters of the headway distributions. For these stops, density plots of consecutive headways are also produced. Sensitivity analysis is carried out to identify the effect of key parameters (dispatching headway, maximum load and running time).

141. Optimization of Headways and Departure Times in Urban Bus Networks: A Case Study of Corlu, Turkey

1. Ceylan, Huseyin; Ozcan, Tayfun
2. ADVANCES IN CIVIL ENGINEERING

The traffic congestion, which has become one of the major problems of developed and developing countries, has led to a shift in the way public transport systems are viewed, and it has accelerated efforts to increase the efficiency of these systems. In recent studies, several approaches, in which both user and operator benefits are evaluated together in order to increase the demand for public transportation systems and to ensure the sustainability of these systems, are emphasized. In this study, a bilevel simulation/optimization model is developed to optimize service headways and departure times of first buses from the beginning of the routes in urban bus networks. At the upper level of the proposed model, a multiobjective function representing user and operator costs is evaluated using the metaheuristic harmony search (HS) optimization technique. The transit assignment problem, which

represents the distribution of transit users over the routes, is handled at the lower level. In the proposed model, the transit assignment problem is solved by the timetable-based assignment approach with VISUM transport planning software. The timetable-based transit assignment is an approach in which the perception errors within the users' route choice are taken into consideration and the transfer wait times can be precisely calculated. The proposed model is applied to a real-life urban bus network of the Corlu district (Tekirda, Turkey), and the effectiveness of the model on a medium-sized urban bus system has been demonstrated. The results show that the user and operator benefits can be simultaneously increased by adding an initial departure offset parameter to the problem.

142. Generating route choice sets with operation information on metro networks

1. Zhu, Wei; Xu, Ruihua

2. JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING-ENGLISH EDITION

In recent years, the metro system has advanced into an efficient transport system and become the mainstay of urban passenger transport in many mega-cities. Passenger flow is the foundation of making and coordinating operation plans for the metro system, and therefore, a variety of studies were conducted on transit assignment models. Nevertheless route choice sets of passengers also play a paramount role in flow estimation and demand prediction. This paper first discusses the main route constraints of which the train schedule is the most important, that distinguish rail networks from road networks. Then, a two-step approach to generate route choice set in a metro network is proposed. Particularly, the improved approach introduces a route filtering with train operational information based on the conventional method. An initial numerical test shows that the proposed approach gives more reasonable route choice sets for scheduled metro networks, and, consequently, obtains more accurate results from passenger flow assignment. Recommendations for possible opportunities to apply this approach to metro operations are also provided, including its integration into a metro passenger flow assignment and simulation system in practice to help metro authorities provide more precise guidance information for passengers to travel. (c) 2016 Periodical Offices of Chang'an University. Production and hosting by Elsevier B.V. on behalf of Owner.

143. Estimation of transit passenger origin-destination matrices from passenger counts in congested transit networks

1. Lam, WHK; Wu, ZX

2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

This paper deals with the transit passenger origin-destination (O-D) estimation problem using updated passenger counts and outdated prior O-D matrix while congestion in transit networks is considered. The bi-level programming approach is extended for the transit passenger O-D updating problem where the sum of error measurements in passenger counts and O-D matrices are minimized in the upper level and the stochastic user equilibrium assignment problem is solved in the lower level for congested transit networks. The transit assignment framework is a frequency-based transit assignment model in this paper, which can cater for elastic line frequencies and passenger overload delays due to congestion at transit stations. A heuristic solution algorithm is adapted for solving the transit passenger O-D estimation problem. Finally, a case study on a simplified transit network connecting Kowloon urban area and the Hong Kong International Airport was employed to illustrate the applications of the proposed model and solution algorithm.

144. A congested and dwell time dependent transit corridor assignment model

1. Alonso, Borja; Carlos Munoz, Juan; Ibeas, Angel; Luis Moura, Jose

2. JOURNAL OF ADVANCED TRANSPORTATION

This research proposes an equilibrium assignment model for congested public transport corridors in urban areas. In this model, journey times incorporate the effect of bus queuing on travel times and boarding and alighting passengers on dwell times at stops. The model also considers limited bus capacity leading to longer waiting times and more uncomfortable journeys. The proposed model is applied to an example network, and the results are compared with those obtained in a recent study. This is followed by the analysis and discussion of a real case application in Santiago de Chile. Finally, different boarding and alighting times and different vehicle types are evaluated. In all cases, demand on express services tends to be underestimated by using constant dwell time assignment models, leading to potential planning errors for these lines. The results demonstrate the importance of considering demand dependent dwell times in the assignment process, especially at high demand levels when the capacity constraint should also be considered. Copyright (C) 2017 John Wiley & Sons, Ltd.

145. Hybrid Modeling of Passenger and Vehicle Traffic along a Transit Line: a sub-model ready for inclusion in a model of traffic assignment to a capacitated transit network

1. Poulhes, Alexis; Pivano, Cyril; Leurent, Fabien

2. 20TH EURO WORKING GROUP ON TRANSPORTATION MEETING, EWGT 2017

The CapTA model of traffic assignment to a large transit network is aimed to deal with traffic phenomena, including a range of capacity constraints, as well as with passenger route choice (Leurent et al, 2014). To this end it has a 3-layer architecture that involves (i) passenger route choice on a network of transit legs and pedestrian links, (ii) line coordination of service missions, vehicle runs with their link running times and station dwelling times, track occupancy and passenger waiting at stations, (iii) vehicle running, including the alighting and boarding of passengers in relation to run dwelling time at the station, in-vehicle passenger load in relation to seat capacity and total vehicle capacity. Yet the line model is macroscopic both for passenger flows and for vehicles serving a given mission, through a frequency variable per station. The paper brings about a novel, hybrid line model that can be used on a standalone basis at the line level or by inclusion in a three-layered model such as CapTA. In the model, a macroscopic representation of passenger flows is hybridized with a microscopic simulation of vehicles. This enables us to simulate headway (ir-)regularity and derive its consequences on vehicle loads, passenger wait times and on-board comfort, track occupancy and vehicle delay for railway modes. The resulting leg generalized times will be used to better simulate optimal travel strategies for path choice in a network in traffic assignment models such as CapTA. After presenting the model and the simulation algorithm, we provide an application to a metro line under two alternative operational policies. (c) 2017 The Authors. Published by Elsevier B.V. Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.

146. Probit-type reliability-based transit network assignment

1. Yang, Liu; Lam, William H. K.

2. TRANSPORTATION RESEARCH RECORD-SERIES

This paper proposes a new probit-type reliability-based transit assignment model in a congested network with unreliable transit services. A new disutility function is developed to model the passenger route choice behavior under unreliable conditions; passengers will make a trade-off between the transit service reliability and the expected travel time for their route choice. In the proposed model, the total transit passenger demand is fixed, but the in-vehicle travel times by transit routes are formulated stochastically because of unreliable traffic conditions, particularly for buses on the road network. The effects of congestion on transit networks, such as elastic transit line frequencies and passenger overload delays, are also considered in the proposed model. A numerical example is provided to illustrate the applications of the proposed model and solution algorithm. It is shown that the traditional probit-type stochastic user equilibrium transit assignment is a special case of the proposed model. The findings also reveal the distribution of passenger waiting times and their overload delays at congested transit stations.

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

1. Schmoecker, Jan-Dirk; Bell, Michael G. H.; Kurauchi, Fumitaka
2. TRANSPORTATION AND TRAFFIC THEORY 2009: GOLDEN JUBILEE

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

148. Simulating the effects of real-time crowding information in public transport networks

1. Drabicki, Arkadiusz; Kucharski, Rafal; Cats, Oded; Fonzone, Achille
2. 2017 5TH IEEE INTERNATIONAL CONFERENCE ON MODELS AND TECHNOLOGIES FOR INTELLIGENT TRANSPORTATION SYSTEMS (MT-ITS)

The objective of this paper is to understand the consequences of providing real-time information on crowding levels (RTI-CL) in public transport networks. We propose to extend the mesoscopic, simulation-based assignment model with the passengers' knowledge of instantaneous crowding levels on-board the public transport vehicles. We illustrate the results on a sample transit network, where we investigate the arising changes in network performance and journey experience as a result of RTI-CL provision. We demonstrate that effects of providing the crowding information in real-time on en-route path choices is strongly related to number of assumptions that we address in the paper. The resulting changes are dependent on: network congestion level (the effects are mostly pronounced in moderately congested networks), passengers' behaviour (increased sensitivity to crowding induces higher variability in vehicle loads), the RTI-CL penetration rate (network performance becomes worse with ubiquitous access to information) and information provision type (smoothed information over recent

vehicle runs leads to higher accuracy than instantaneous information based on the single latest run only). Based on these, we formulate conclusions for further studies, larger-scale applications and practical implementation of real-time passenger crowding information systems.

149. Penalization and augmented Lagrangian for O-D demand matrix estimation from transit segment counts

1. Chavez Hernandez, Maria Victoria; Juarez Valencia, Lorenzo Hector; Rios Solis, Yasmin Agueda
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

In this paper we consider some penalized quadratic models to update Origin-Destination (O-D) matrices in transit networks from observed flows. These models look for the closest O-D matrix to an outdated one, which reproduces some observed segment flows. We demonstrate that the solution of these penalized models converges to the solution of the Spiess model when the penalty parameter increases to infinity. Another contribution is the introduction of an augmented Lagrangian model and its iterative solution by a dual ascent technique and the method of multipliers. This approach yields high-quality solutions with low CPU time and it is tested with two networks: the Winnipeg transit network, which has 23716 O-D pairs; and the transit network of the metropolitan area of the Valley of Mexico with more than 2 million of O-D pairs. For some instances, extracting the null coefficients from the old O-D matrix reduces the computational cost even further.

150. Short-term rail rolling stock rostering and maintenance scheduling

1. Giacco, Giovanni Luca; Carillo, Donato; D'Ariano, Andrea; Pacciarelli, Dario; Marin, Angel G.
2. 17TH MEETING OF THE EURO WORKING GROUP ON TRANSPORTATION, EWGT2014

This paper describes an optimization framework for railway rolling stock rostering and maintenance scheduling. A key problem in railway rostering planning requires covering a given set of services and maintenance works with limited rolling stock units. The problem is solved via a two-step approach that combines the scheduling tasks related to train services, short-term maintenance operations and empty runs. A commercial MIP solver is used for the development of a real-time decision support tool. A campaign of experiments on real-world scenarios from Trenitalia (Italian train operating company) illustrates the improvement achievable by the approach when compared to the practical solutions. (C) 2014 The Authors. Published by Elsevier B.V.

151. Potential travel cost saving in urban public-transport networks using smartphone guidance

1. Song, Cuiying; Guan, Wei; Ma, Jihui
2. PLOS ONE

Public transport (PT) is a key element in most major cities around the world. With the development of smartphones, available journey planning information is becoming an integral part of the PT system. Each traveler has specific preferences when undertaking a trip, and these preferences can also be reflected on the smartphone. This paper considers transit assignment in urban public-transport networks in which the passengers receive smartphone-based information containing elements that might influence the travel decisions in relation to line loads, as well as passenger benefits, and the paper discusses the transition from the current widespread choosing approach to a personalized decision-making approach based on smartphone information. The approach associated with

smartphone guidance that considers passengers' preference on travel time, waiting time and transfer is proposed in the process of obtaining his/her preferred route from the potential travel routes generated by the Deep First Search (DFS) method. Two other approaches, based on the scenarios reflecting reality, include passengers with access to no real time information, and passengers that only have access to the arrival time at the platform are used as comparisons. For illustration, the same network proposed by Spiess and Florian is utilized on the experiments in an agent-based model. Two experiments are conducted respectively according to whether each passenger's choosing method is consistent. As expected, the results in the first experiment showed that the travel for consistent passengers with smartphone guidance was clearly shorter and that it can reduce travel time exceeding 15% and weighted cost exceeding 20%, and the average saved time approximated 3.88 minutes per passenger. The second experiment presented that travel cost, as well as cost savings, gradually decreased by employing smartphone guidance, and the maximum cost savings accounted for 14.2% of the total weighted cost.

152. Modelling public transport on-board congestion: comparing schedule-based and agent-based assignment approaches and their implications

1. Cats, Oded; Hartl, Maximilian
2. JOURNAL OF ADVANCED TRANSPORTATION

Transit systems are subject to congestion that influences system performance and level of service. The evaluation of measures to relieve congestion requires models that can capture their network effects and passengers' adaptation. In particular, on-board congestion leads to an increase of crowding discomfort and denied boarding and a decrease in service reliability. This study performs a systematic comparison of alternative approaches to modelling on-board congestion in transit networks. In particular, the congestion-related functionalities of a schedule-based model and an agent-based transit assignment model are investigated, by comparing VISUM and BusMezzo, respectively. The theoretical background, modelling principles and implementation details of the alternative models are examined and demonstrated by testing various operational scenarios for an example network. The results suggest that differences in modelling passenger arrival process, choice-set generation and route choice model yield systematically different passenger loads. The schedule-based model is insensitive to a uniform increase in demand or decrease in capacity when caused by either vehicle capacity or service frequency reduction. In contrast, nominal travel times increase in the agent-based model as demand increases or capacity decreases. The marginal increase in travel time increases as the network becomes more saturated. Whilst none of the existing models capture the full range of congestion effects and related behavioural responses, existing models can support different planning decisions. Copyright (c) 2016 John Wiley & Sons, Ltd.

153. Strategy-based transit stochastic user equilibrium model with capacity and number-of-transfers constraints

1. Li, Guoyuan; Chen, Anthony
2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

Vehicle capacity and number-of-transfers constraints are critical in transit network equilibrium because (1) transit vehicles cannot carry passengers over their capacity and (2) transit passengers typically avoid paths with numerous transfers. In this paper, we propose a strategy-based transit stochastic user equilibrium (SUE) model that considers capacity and number-of-transfers constraints for an urban

congested transit network. A route-section-based method is used for the transit network representation. The transit passengers' route choice behavior is assumed to obey the logit model, and a route-section-based path size correction factor is developed to handle the route overlapping issue. The transit line capacity and maximum number-of-transfers constraints are considered in the model. We then formulate the strategy-based transit SUE problem as a variational inequality (VI) problem. A transit path-set generation procedure is proposed to identify a transit path with a limited number of transfers using the route-section-based network representation. The diagonalization method is chosen to solve the VI problem due to the asymmetric cost function, and the diagonalized problem can be solved using a path-based partial linearization algorithm embedded with an iterative balancing scheme, which is used here to handle the numerous capacity constraints. Numerical examples are conducted to demonstrate the features of the proposed model and performance of the developed algorithm. The results show that the vehicle capacity and number of transfers would strongly impact the passenger flow patterns. (c) 2022 Elsevier B.V. All rights reserved.

154. User perspectives in public transport timetable optimisation

1. Parbo, Jens; Nielsen, Otto Anker; Prato, Carlo Giacomo
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

The present paper deals with timetable optimisation from the perspective of minimising the waiting time experienced by passengers when transferring either to or from a bus. Due to its inherent complexity, this bi-level minimisation problem is extremely difficult to solve mathematically, since timetable optimisation is a non-linear non-convex mixed integer problem, with passenger flows defined by the route choice model, whereas the route choice model is a non-linear non-continuous mapping of the timetable. Therefore, a heuristic solution approach is developed in this paper, based on the idea of varying and optimising the offset of the bus lines. Varying the offset for a bus line impacts the waiting time passengers experience at any transfer stop on the bus line. In the bi-level timetable optimisation problem, the lower level is a transit assignment calculation yielding passengers' route choice. This is used as weight when minimising waiting time by applying a Tabu Search algorithm to adapt the offset values for bus lines. The updated timetable then serves as input in the following transit assignment calculation. The process continues until convergence. The heuristic solution approach was applied on the large-scale public transport network in Denmark. The timetable optimisation approach yielded a yearly reduction in weighted waiting time equivalent to approximately 45 million Danish kroner (9 million USD). (C) 2014 Elsevier Ltd. All rights reserved.

155. Large-scale application of MILATRAS: case study of the Toronto transit network

1. Wahba, Mohamed; Shalaby, Amer
2. TRANSPORTATION

This paper documents the efforts to operationalize the conceptual framework of Microsimulation Learning-based Approach to TRansit Assignment (MILATRAS) and its component models of departure time and path choices. It presents a large-scale real-world application, namely the multi-modal transit network of Toronto which is operated by the Toronto Transit Commission (TTC). This large-scale network is represented by over 500 branches with more than 10,000 stops. About 332,000 passenger-agents are modelled to represent the demand for the TTC in the AM peak period. A learning-based departure time and path choice model was adopted using the concept of mental models for the modelling of the transit assignment problem. The choice model parameters were calibrated such that

the entropy of the simulated route loads was optimized with reference to the observed route loads, and validated with individual choices. A Parallel Genetic Algorithm engine was used for the parameter calibration process. The modelled route loads, based on the calibrated parameters, greatly approximate the distribution underlying the observed loads. 75% of the exact sequence of transfer point choices were correctly predicted by the off-stop/on-stop choice mechanism. The model predictability of the exact sequence of route transfers was about 60%. In this application, transit passengers were assumed to plan their transit trip based on their experience with the transportation network; with no prior (or perfect) knowledge of service performance.

156. Passenger Assignment Model Based on Common Route in Congested Transit Networks

1. Ren, Hualing; Long, Jiancheng; Gao, Ziyu; Orenstein, Penina
2. JOURNAL OF TRANSPORTATION ENGINEERING

In this paper, the common line problem and passengers' choice behaviors in transit networks are revisited and discussed. The concept of the common line problem is extended to represent a common route problem in transit networks. The transit routes are classified into various levels of attractive route sets according to route fixed costs and route frequencies. The transit passenger assignment problem on congested transit networks is defined to assign passenger flows on attractive route sets and is formulated as a variational inequality (VI) problem. In the proposed model, the effective frequency approach is applied to reflect the effects of passenger congestion on the waiting time at the stations. Compared with traditional models, the proposed passenger flow assignment model does not require a modification to the transit network nor a constant recomputation of the changing attractive line set. Finally, a simple example is used to illustrate the difference between common line and common route methods, and the passengers' travel behaviors under various transit conditions are demonstrated on the Sioux Falls transit network. DOI: 10.1061/(ASCE)TE.1943-5436.0000464. (C) 2012 American Society of Civil Engineers.

157. A Hybrid Cross Entropy Algorithm for Solving Dynamic Transit Network Design Problem

1. Ma, Tai-Yu
2. JOURNAL OF INFORMATION SCIENCE AND ENGINEERING

This paper proposes a hybrid multiagent learning algorithm for solving the dynamic simulation-based bilevel network design problem. The objective is to determine the optimal frequency of a multimodal transit network, which minimizes total users' travel cost and operation cost of transit lines. The problem is formulated as a bilevel programming problem with equilibrium constraints describing non-cooperative Nash equilibrium in a dynamic simulation-based transit assignment context. A hybrid algorithm combining the cross entropy multiagent learning algorithm and Hooke-Jeeves algorithm is proposed. Computational results are provided on the Sioux Falls network to illustrate the performance of the proposed algorithm.

158. A hybrid multiagent learning algorithm for solving the dynamic simulation-based continuous transit network design problem

1. Ma, Tai-Yu
2. 2011 INTERNATIONAL CONFERENCE ON TECHNOLOGIES AND APPLICATIONS OF ARTIFICIAL INTELLIGENCE (TAAI 2011)

This paper proposes a hybrid multiagent learning algorithm for solving the dynamic simulation-based bilevel network design problem. The objective is to determine the optimal frequency of a multimodal transit network, which minimizes total users' travel cost and operation cost of transit lines. The problem is formulated as a bilevel programming problem with equilibrium constraints describing noncooperative Nash equilibrium in a dynamic simulation-based transit assignment context. A hybrid algorithm combining the cross entropy multiagent learning algorithm and Hooke-Jeeves algorithm is proposed. Computational results are provided on a small network to illustrate the performance of the proposed algorithm.

159. Reliability assessment on transit network services

1. Yin, YF; Lam, WHK; Ieda, H
2. NETWORK RELIABILITY OF TRANSPORT, PROCEEDINGS

This paper attempts to assess the transit service reliability with taking into account the interaction between network performance and passengers' travel choice behaviors. Besides the well-known schedule reliability, a waiting-time reliability is newly defined as the probability that the passengers' average waiting time is less than a given threshold. A Monte Carlo simulation approach, which incorporates a stochastic user equilibrium transit assignment model with explicit capacity constraints and elastic frequencies, is proposed to estimate the above two reliability measures of transit service. A numerical example is used to illustrate the applicability of the reliability measures and the proposed approach.

160. Passenger Route Choice Behavior with Congestion Consideration

1. Zeng, Ying; Li, Jun; Zhu, Hui
2. FRONTIERS OF GREEN BUILDING, MATERIALS AND CIVIL ENGINEERING III, PTS 1-3

Few studies have adequately focused on passenger route choice behavior with congestion consideration, or provided useful guidance on passenger route choice and hence the transit assignment model, which is the writing motivation of this paper. With congestion consideration, travel cost is assessed and ways to reduce it also identified. Finally, an actual transit network of Chengdu is used as a case study to demonstrate the benefits of the proposed model. The result indicates that the vehicle capacity is an important factor that can't be ignored and a better understanding of passenger route behavior could significantly benefit public transit system.

161. Dynamic Vulnerability Analysis of Public Transport Networks: Mitigation Effects of Real-Time Information

1. Cats, Oded; Jenelius, Erik
2. NETWORKS & SPATIAL ECONOMICS

In this paper, a dynamic and stochastic notion of public transport network vulnerability is developed. While previous studies have considered only the network topology, the granular nature of services requires a more refined model for supply and demand interactions in order to evaluate the impacts of disruptions. We extend the measures of betweenness centrality (often used to identify potentially important links) and link importance to a dynamic-stochastic setting from the perspectives of both operators and passengers. We also formalize the value of real-time information (RTI) provision for reducing disruption impacts. The developed measures are applied in a case study for the high-

frequency public transport network of Stockholm, Sweden. The importance ranking of the links varies depending on the RTI provision scheme. The results suggest that betweenness centrality (passenger/vehicle flows) may not be a good indicator of link importance. The results of the case study reveal that while service disruptions have negative effects and RTI may have significant positive influence, counter examples also exist due to secondary spillover effects.

162. A trip-chain-based combined mode and route-choice network equilibrium model

1. Shimamoto, Hiroshi; Higuchi, Takashi; Uno, Nobuhiro; Shiomi, Yasuhiro
2. TRANSPORTMETRICA B-TRANSPORT DYNAMICS

This paper proposes a trip-chain-based mode and route-choice network equilibrium model that considers the common lines problem' in transit assignment. The proposed model assumes the nested-logit type of mode and route-choice structure for the travellers' mode and route choice. The proposed model is formulated using the variational inequality problem, and the relaxation method is applied to solve the proposed model. Finally, the proposed model is applied to hypothetical networks, and confirms that the differences in the total mode share, link flows, and link travel times between the proposed model and the traditional trip-based assignment model are not large. We also confirmed that the some trip-chains differed considerably in mode share.

163. A simulation-based reliability assessment approach for congested transit network

1. Yin, Y; Lam, WHK; Miller, MA
2. JOURNAL OF ADVANCED TRANSPORTATION

This paper is an attempt to develop a generic simulation-based approach to assess transit service reliability, taking into account interaction between network performance and passengers' route choice behaviour. Three types of reliability, say, system wide travel time reliability, schedule reliability and direct boarding waiting-time reliability are defined from perspectives of the community or transit administration, the operator and passengers. A Monte Carlo simulation approach with a stochastic user equilibrium transit assignment model embedded is proposed to quantify these three reliability measures of transit service. A simple transit network with a bus rapid transit (BRT) corridor is analysed as a case study where the impacts of BRT components on transit service reliability are evaluated preliminarily.

164. Estimation of time-dependent origin-destination matrices for transit networks

1. Wong, SC; Tong, CO
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

In this paper, the estimation of time-dependent origin-destination (O-D) matrices for transit network based on observed passenger counts is given. The dynamic assignment framework is based on a schedule-based transit network model, which can help determine the time-dependent least cost paths between all O-D pairs, and for each of them the clock arrival times at the end nodes of all observed links (if any) in the transit network. An entropy-based approach is then employed to estimate the time-dependent O-D matrices based on the observed passenger counts at those observed links in the network. An efficient sparse algorithm is also proposed to solve the resulting mathematical programming problem. The estimation methodology is tested in a transit network from the Mass Transit Railway (MTR) system in Hong Kong which is one of the busiest railway systems in the world.

Both cases with and without prior information of the O-D matrices are considered for this network. The predicted matrices are then compared with the true matrices obtained from a sophisticated electronic fare collection system of MTR. Good agreement between predicted and observed matrices are found.
(C) 1998 Elsevier Science Ltd.

165. MODELLING THE EFFECTS OF ETIS MARKET PENETRATION IN NETWORK WITH UNRELIABLE TRANSIT SERVICES

1. Yang, Liu; Lam, William H. K.
2. TRANSPORTATION STUDIES: SUSTAINABLE TRANSPORTATION, PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

This paper aims to model the effects of ETIS market penetration on transit network performance (in terms of total passenger travel time), particularly when the transit services are unreliable and the transit network is congested. A new bi-level model is proposed to formulate ETIS market penetration effects on congested transit network. The upper-level problem is to minimize the total passenger travel time, which reflects the transit network performance. While the lower-level problem is a multi-class reliability-based stochastic user equilibrium transit assignment model. Transit congestion effects, such as elastic line frequencies and passenger overload delays, are also considered explicitly in the lower-level problem. Numerical results indicate that ETIS market penetration has significant impacts on transit network performance and passenger route choice behaviors.

166. OPTIMIZATION OF TRANSIT PRIORITY IN THE TRANSPORTATION NETWORK USING A DECOMPOSITION METHODOLOGY

1. Mesbah, Mahmoud; Sarvi, Majid; Ouveysi, Iradj; Currie, Graham
2. 18TH INTERNATIONAL SYMPOSIUM ON TRANSPORTATION AND TRAFFIC THEORY

A new methodology to optimize transit priority is proposed in this paper. Having a higher passenger capacity than private cars, transit vehicles can increase the passenger throughput of roads. This is the main basis for justifying the provision of exclusive transit lanes. Although a range of studies have addressed exclusive transit lanes, all have a localized focus in nominating a transit priority alternative. This paper is aimed at finding the optimum combination of exclusive transit lanes on a network basis. Transit priority is formulated as a bi-level optimization programming which considers modal split, traffic assignment, and transit assignment. A decomposition method is adapted for solving the proposed mathematical model which converges to the optimal solution. The method is also demonstrated in an example network.

167. Optimal fare structure for transit networks with elastic demand

1. Lam, WHK; Zhou, J
2. TRANSPORTATION NETWORK PLANNING: PLANNING AND ADMINISTRATION

A bilevel model is presented to optimize the fare structure for transit networks with elastic demand under the assumption of fixed transit service frequency. It is known that the transit fare structure has significant effects on passengers' demand and route choice behavior. The transit operator therefore should predict passengers' response to changing fare charges. A bilevel programming method is developed to determine the optimal fare structure for the transit operator while taking passengers' response into account. The upper-level problem seeks to maximize the operator's revenue, whereas

the lower-level problem is a stochastic user equilibrium transit assignment model with capacity constraints. A heuristic solution algorithm based on sensitivity analysis is proposed. Finally, a numerical example is given together with some useful discussion.

168. Integrated Railway Rapid Transit Network Design and Line Planning problem with maximum profit

1. Canca, David; De-Los-Santos, Alicia; Laporte, Gilbert; Mesa, Juan A.
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

We solve the Integrated Network Design and Line Planning Problem in Railway Rapid Transit systems with the objective of maximizing the net profit over a planning horizon, in the presence of a competing transportation mode. Since the profitability of the designed network is closely related with passengers' demand and line operation decisions, for a given demand, a transit assignment is required to compute the profit, calculating simultaneously the frequencies of lines and selecting the most convenient train units. The proposed iterative solving procedure is governed by an adaptive large neighborhood search metaheuristic which, at each iteration, calls a branch-and-cut algorithm implemented in Gurobi in order to solve the assignment and network operation problems. We provide an illustration on a real-size scenario.

169. Finding shortest time-dependent paths in schedule-based transit networks: A label setting algorithm

1. Florian, M
2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

The basic building block of a schedule-based transit assignment problem is to find an optimal path for a passenger, given an origin node, a destination node and departure or arrival preferences. The schedule-based shortest time-dependent transit shortest path does not minimize always the total time of a trip; rather, it uses weight factors and preferences regarding departure and arrivals to determine the best path which satisfies the trip specifications. The algorithm, which is based on a label-setting scheme (Dijkstra, 1959) tracks both times (to determine the feasibility of a path) and cost (to determine the attractiveness of a path). This paper describes the model and the algorithm for this schedule-based deterministic temporal shortest path model.

170. USING ACCESSIBILITY MEASURES IN TRANSIT NETWORK DESIGN

1. Gulhan, Gorkem; Ceylan, Huseyin; Ceylan, Halim
2. TRANSPORT

Transit planning scenarios may lead to the different Objective Function (OF) values since each scenario has different transit travel times, frequencies and fleet sizes. Change on those variables leads to the different accessibility values for each route set. Therefore, the actual performance of a route set may be unforeseen since the accessibility values are out of evaluation criteria. This study tries to generate techniques, which handle the relation between accessibility and transportation in the scope of public transit. The accessibility measures, which have direct relation with land use and transportation, are utilized in transit route set decision. Accessibility measures have been utilized in the decision-making process of transit network design. Conventional OFs, which are used to determine the most effective route sets are combined with accessibility based OFs and the decision-making process of transit

network design is strengthened. In this context, the effects of accessibility measures in decision-making process of transit network design have been represented on an 8-node example transit network. The results showed the accessibility measures could effectively improve the planners' decision accuracy.

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

1. Kim, Ikki; Kim, Hyung-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 circuitry index.

172. Transit network reliability: An application of absorbing Markov chains

1. Bell, MGH; Schmoecker, JD; Lam, WHK
2. TRANSPORTATION AND TRAFFIC THEORY IN THE 21ST CENTURY

An absorbing Markov chain model is applied to transit assignment to analyse the impact of vertex failure on the probability of trip failure. Vertex failure probabilities are treated as either known or unknown, and if unknown then worst vertex failure probabilities are sought. Lessons learnt from recent random graph research on the robustness of different network topologies are reviewed. An analysis of a number of elemental transit network topologies using the absorbing Markov chain model shows that the hub-and-spoke graph is the most robust to random vertex failure but also among the most vulnerable to directed vertex attack. A particular form of unreliability, namely the probability of being unable to board a transit line due to insufficient capacity, is analysed using the absorbing Markov chain model.

173. Optimal transit fare and service frequency of a nonlinear origin-destination based fare structure

1. Huang, Di; Liu, Zhiyuan; Liu, Pan; Chen, Jun
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

This paper proposes a new nonlinear distance-based transit fare structure, which is measured by a function of the Euclidean distance between the origin and destination stations, termed as Origin-Destination (OD)-based fare. The novel fare structure encourages passengers to freely choose the most efficient trip plan. An optimization model is formulated based on a three-party game (involving the transport authority, transit company, and passenger) to determine the optimal fare function and frequency. An artificial bee colony algorithm is adopted to solve the model. Finally, a numerical example is provided to verify the proposed method. (C) 2016 Elsevier Ltd. All rights reserved.

174. A LARGE SCALE APPLICATION OF A HYPERPATH BASED RAILWAY ROUTE ASSIGNMENT MODEL CONSIDERING CONGESTION EFFECTS TO TOKYO METROPOLITAN AREA

1. Yaginuma, Hideki; Fukuda, Daisuke; Schmoecker, Jan-Dirk
2. TRANSPORTATION AND URBAN SUSTAINABILITY

This paper applies a frequency-based transit assignment considering congestion effects to the large-scale urban railway network in Tokyo Metropolitan Area. Our model formulation is based on the pioneering work by Spiess and Florian (1989) but we further incorporate the effective frequency described by the BPR type function as well as the disutility caused by the in-vehicle congestion. The computational complexity of this problem is discussed and some parallelization technique is newly developed for reducing computational time. For our empirical results, commuting passengers' data taken from Tokyo Metropolitan Railway Census 2005 and railway timetable information (e.g. in-vehicle time and frequencies) are combined. The empirical results indicate that the proposed model has better goodness of fit compared to the case with no consideration of congestion.

175. Optimization of transit priority in the transportation network using a decomposition methodology

1. Mesbah, Mahmoud; Sarvi, Majid; Ouveysi, Iradj; Currie, Graham
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

A new methodology to optimize transit priority is proposed in this paper. Having a higher passenger capacity than private cars, transit vehicles can increase the passenger throughput of roads. This is the main basis for justifying the provision of exclusive transit lanes. Although a range of studies have addressed exclusive transit lanes, all have a localized focus in nominating a transit priority alternative. This paper is aimed at finding the optimum combination of exclusive transit lanes on a network basis. Transit priority is formulated as a bi-level optimization programming which considers modal split, traffic assignment, and transit assignment. A decomposition method is adapted for solving the proposed mathematical model which converges to the optimal solution. The method is also demonstrated in an example network. (C) 2010 Elsevier Ltd. All rights reserved.

176. A capacity restraint assignment model for congested public transport systems

1. Lam, WHK; Gao, ZY; Chan, KS
2. TRAFFIC AND TRANSPORTATION STUDIES

In this paper, a time-dependent capacity restraint assignment model is proposed for transit networks with passenger queues and congestion at stations. In this model the passenger waiting cost is a function of both combined frequency of the transit lines and congestion at stations because of insufficient capacities of transit lines in a particular time period. The conservation of the time-

dependent passenger flows and queues at any station is derived and incorporated in the proposed model. The objective is to minimize the sum of the expected total passenger travel time (including waiting time) and the total number of passenger queues at stations in the study period. An equivalent mathematical programming problem is formulated for the time-dependent transit system optimization assignment and the solution algorithm is proposed. Numerical example is used to illustrate the applications of the new transit assignment model.

177. DYNAMIC ESTIMATION OF PASSENGER ORIGIN-DESTINATION MATRIX FOR CONGESTED TRANSIT NETWORKS

1. Ren, H. L.; Lam, William H. K.; Gao, Z. Y.
2. TRANSPORTATION STUDIES: SUSTAINABLE TRANSPORTATION, PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

This paper investigates the problem of estimation of time-dependent passenger origin-destination (O-D) matrices in congested transit networks where real-time updated passenger counts and prior O-D matrices are available. A bi-level programming model is proposed for the dynamic estimation of passenger O-D matrix. The upper level minimizes the sum of error measurements in dynamic passenger counts and time-dependent O-D matrices, and the lower level is a new schedule-based dynamic transit assignment model that can determine simultaneously the dynamic average travel costs and route choices of passengers in congested transit networks. The lower-level problem can be formulated as a variational inequality problem. A heuristic solution algorithm is adapted for solving the proposed bi-level programming model. Finally, a numerical example is used to illustrate the applications of the proposed model and solution algorithm.

178. Origin-destination demands estimation in congested dynamic transit networks

1. Ren Hua-Ling
2. PROCEEDINGS OF 2007 INTERNATIONAL CONFERENCE ON MANAGEMENT SCIENCE & ENGINEERING (14TH) VOLS 1-3

This paper investigates the problem of estimation of time-dependent passenger origin-destination (OD) matrices in congested transit networks where real-time updated passenger counts and prior OD matrices are available. A bilevel programming model is proposed for the dynamic estimation of passenger OD matrix. The upper level minimizes the sum of error measurements in dynamic passenger counts and time-dependent CD matrices, and the lower level is a new schedule-based dynamic transit assignment model that can determine simultaneously the dynamic average travel costs and route choices of passengers in congested transit networks. The lower-level problem can be formulated as a variational inequality problem. A heuristic solution algorithm is adapted for solving the proposed bilevel programming model. Finally, a numerical example is used to illustrate the applications of the proposed model and solution algorithm.

179. Theoretical substantiation of trip length distribution for home-based work trips in urban transit systems

1. Horbachov, Peter; Svichynskyi, Stanislav
2. JOURNAL OF TRANSPORT AND LAND USE

Modern approaches to the modeling of transport demand imply the use of calibration procedures during the origin-destination (O-D) matrix estimation or transit assignment. These procedures lead to misrepresenting generated and attracted trips or changing the trip length distribution (TLD). It means that the methods of transport planning can be improved by means of determination, validation and implementation of the TLD to calculate the O-D matrix. The analysis of research results in the field of mass transit reveals an explicit similarity between TLD in different cities and the gamma distribution. It points to general regularities in various systems of mass transit that lead to the similarity in TLD. The regularities are determined by studying the spatial distribution of mass transit stops, which are considered trip origins and destinations. The experimental research was conducted in 10 Ukrainian cities using probability theory methods.

180. Transit interchange discount optimization using an agent-based simulation model

1. Lee, Enoch; Patwary, Ashraf Uz Zaman; Huang, Wei; Lo, Hong K.
2. 11TH INTERNATIONAL CONFERENCE ON AMBIENT SYSTEMS, NETWORKS AND TECHNOLOGIES (ANT) / THE 3RD INTERNATIONAL CONFERENCE ON EMERGING DATA AND INDUSTRY 4.0 (EDI40) / AFFILIATED WORKSHOPS

Transit interchange discounts encourage people to travel by public transport, increasing the revenue of the operators. This research develops a transit assignment model, which takes account of the actual travel time, congestion and fare of the public transport, using an agent-based simulation model MATSim. Then, a simulation-based optimization problem is formulated to optimize the interchange discount to maximize profit. For computational efficiency, a metamodeling technique is further proposed and the metamodel can serve as a surrogate of the expensive simulation process. Transfer hubs are set up in a Hong Kong Island scenario and the interchange discount for bus-bus interchanges is optimized. The optimization result shows that the optimal interchange discount optimized by the proposed metamodel-based method increases the bus operators' profit by 12%. (C) 2020 The Authors. Published by Elsevier B.V.

181. Modeling Transit and Intermodal Tours in a Dynamic Multimodal Network

1. Khani, Alireza; Bustillos, Brenda; Noh, Hyunsoo; Chiu, Yi-Chang; Hickman, Mark
2. TRANSPORTATION RESEARCH RECORD

A fixed-point formulation and a simulation-based solution method were developed for modeling intermodal passenger tours in a dynamic transportation network. The model proposed in this paper is a combined model of a dynamic traffic assignment, a schedule-based transit assignment, and a park-and-ride choice model, which assigns intermodal demand (i.e., passengers with drive-to-transit mode) to the optimal park-and-ride station. The proposed model accounts for all segments of passenger tours in the passengers' daily travel, incorporates the constraint on returning to the same park-and-ride location in a tour, and models individual passengers at a disaggregate level. The model has been applied in an integrated travel demand model in Sacramento, California, and feedback to the activity-based demand model is provided through separate time-dependent skim tables for auto, transit, and intermodal trips.

182. Transit passenger origin-destination estimation in congested transit networks with elastic line frequencies

1. Wu, Z. X.; Lam, William H. K.

2. ANNALS OF OPERATIONS RESEARCH

This paper deals with the transit passenger origin-destination (O-D) estimation problem by using updated passenger counts in congested transit networks and outdated prior O-D matrix. A bilevel programming approach is extended for the transit passenger O-D updating problem where the upper-level problem seeks to minimize the sum of error measurements in passenger counts and O-D matrices, while the lower level is the stochastic user equilibrium assignment problem for congested transit networks. The transit assignment framework is based on a frequency-adaptive transit network model in this paper, which can help determine transit line frequencies and the network flow pattern simultaneously in congested transit networks. A heuristic solution algorithm is adapted for solving the transit passenger O-D estimation problem. Finally, a numerical example is used to illustrate the applications of the proposed model and solution algorithm.

183. A bi-level programming approach - Optimal transit fare under line capacity constraints

1. Zhou, J; Lam, WHK

2. JOURNAL OF ADVANCED TRANSPORTATION

The fare of a transit line is one of the important decision variables for transit network design. It has been advocated as an efficient means of coordinating the transit passenger flows and of alleviating congestion in the transit network. This paper shows how transit fare can be optimized so as to balance the passenger flow on the transit network and to reduce the overload delays of passengers at transit stops. A bi-level programming method is developed to optimize the transit fare under line capacity constraints. The upper-level problem seeks to minimize the total network travel time, while the lower-level problem is a stochastic user equilibrium transit assignment model with line capacity constraints. A heuristic solution algorithm based on sensitivity analysis is proposed. Numerical example is used to illustrate the application of the proposed model and solution algorithm.

184. Transit Travel Strategy as Solution of a Markov Decision Problem: Theory and Applications

1. Nuzzolo, Agostino; Comi, Antonio

2. 2017 5TH IEEE INTERNATIONAL CONFERENCE ON MODELS AND TECHNOLOGIES FOR INTELLIGENT TRANSPORTATION SYSTEMS (MT-ITS)

The search of optimal travel strategy on unreliable transit network is analyzed as solution of a Markov decision problem and two uses of this approach, recently presented by the authors, are recalled and compared. The first application is relative to normative strategy search, such as for path recommendation in innovative transit trip planners. The second use concerns subjective optimal strategy search in a dynamic strategy-based path choice modelling, especially suitable for real-time run-oriented simulation-based mesoscopic assignment models. The paper concludes with an overview of the benefits of the approach and outlines scopes for further research.

185. Route choice on transit networks with online information at stops

1. Gentile, G; Nguyen, S; Pallottino, S

2. TRANSPORTATION SCIENCE

Passengers on a transit network with common lines are often faced with the problem of choosing between either to board the arriving bus or to wait for a faster one. Many assignment models are

based on the classical assumption that at a given stop passengers board the first arriving carrier of a certain subset of the available lines, often referred to as the attractive set. In this case, it has been shown that, if the headway distributions are exponential, then an optimal subset of lines minimizing the passenger travel time can be easily determined. However, when online information on future arrivals of buses are posted at the stop, it is unlikely that the above classical assumption holds. In this case, passengers may choose to board a line that offers the best combination of displayed waiting time and expected travel time to their destination once boarded. In this paper, we propose a general framework for determining the probability of boarding each line available at a stop when online information on bus waiting times is provided to passengers. We will also show that the classical model without online information may be interpreted as a particular instance of the proposed framework, this way achieving an extension to general headway distributions. The impact of the availability of information regarding bus arrivals and that of the regularity of transit lines on the network loads, as well as on the passenger travel times, will be illustrated with small numerical examples.

186. Real-Time passengers forecasting in congested transit networks considering dynamic service disruptions and passenger count data

1. Miristice, Lory Michelle Bresciani; Gentile, Guido; Corman, Francesco; Tididi, Daniele; Meschini, Lorenzo
2. 2023 8TH INTERNATIONAL CONFERENCE ON MODELS AND TECHNOLOGIES FOR INTELLIGENT TRANSPORTATION SYSTEMS, MT-ITS

Congestion phenomena (e.g., crowding, service interruptions, and atypical demand) increasingly affect complex and interconnected public transport networks, resulting in low levels of services and harming the planned schedules. As a result, public transport operators need a tool to compensate for recurrent and non-recurrent congestion phenomena by recovering the service (e.g., introducing new runs) and notifying passengers about crowding (e.g., through real-time information systems). This study suggests a model that forecasts the volumes of passengers in transit networks, including the effects of events and real-time disruptions. In particular, the model performs a run-based macroscopic transit assignment, computing the elastic route choices of users under the assumption that passengers are fully informed. Moreover, the model corrects its forecasts using real-time count data. The model can also include countermeasures, allowing the operators to test several recovery scenarios on large transit networks faster than in real time.

187. An infeasible start heuristic for the transit route network design problem

1. Olikar, Nurit; Bekhor, Shlomo
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

This paper develops an efficient heuristic for the transit network design problem, formulated as an integer programming problem. The model includes a preliminary step of route set generation, followed by an iterative procedure that simultaneously selects the best routes and corresponding headways. The iterative procedure is performed by an infeasible start algorithm that first assigns all candidate routes with the maximal frequency, and then iteratively eliminates routes and decreases frequencies of the less attractive ones. Routes are evaluated through a frequency-based transit assignment model that considers online information. The proposed model is applied to the Winnipeg transit network. The transit network found by the suggested model comprised fewer, faster and more frequent lines that serve high volume of passengers, compared to the given transit network. The running time of the

algorithm is very short compared to existing methods, and its simplicity enables high level and detailed calibration.

188. Estimating Weights of Times and Transfers for Hyperpath Travelers

1. Kurauchi, Fumitaka; Schmoecker, Jan-Dirk; Fonzone, Achille; Hemdan, Seham Mohamed Hassan; Shimamoto, Hiroshi; Bell, Michael G. H.
2. TRANSPORTATION RESEARCH RECORD

In high-frequency transit networks, travelers are often assumed to reduce their travel time by identifying sets of attractive lines. This concept was used in the development of most transit assignment models. Whether transfer penalties and waiting times are more highly valued than onboard travel times largely has been ignored in these assignment models. The literature on the estimation of the value of time for public transport passengers also ignores the complexity of choices faced by transit travelers in large cities. An effort to close this gap addressed the question of whether different passenger groups choose different strategies at stops. A web-based survey was conducted, and data from 597 individuals from various countries were obtained. Hyperpath selection was formulated as a discrete choice model, and the relative weights were estimated. Nested logit models were used to consider the correlation between alternatives within the hyperpath. Results indicated that individual specific attributes significantly influenced passengers' selection of hyperpath.

189. PASSENGER FLOW CONTROL IN CONGESTED TRANSIT NETWORKS

1. Schmocker, Jan-Dirk; Shimamoto, Hiroshi; Kurauchi, Fumitaka; Bell, Michael G. H.
2. TRANSPORTATION SYSTEMS: ENGINEERING & MANAGEMENT

This paper presents an approach to model the impact of ramp metering in public transit assignment. In overcrowded situations the operator might choose to meter the access to platforms for safety reasons and to minimise the delays passengers incur through failing-to-board. The approach is based on introducing a fail-to-access probability at the station entrance if the demand exceeds the available capacity. This fail-to-access probability is also thought to deter passengers from choosing a congested route. In the second part of the paper the ramp metering is then optimised in the form of a bi-level optimisation problem. The control variables are the station-access capacities. An elitist non-dominated sorting Genetic Algorithm is used in order to find the pareto-optimal set of solutions. With an example it is illustrated that it might be beneficial to introduce ramp metering for the operator as well as for the passenger.

190. Risk-Based Formulation of the Transit Priority Network Design

1. Ghaffari, Ahmadreza; Mesbah, Mahmoud; Khodaii, Ali; MirHassani, S. Ali
2. IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS

Demand uncertainties are inevitable in transportation networks. The transit priority network design problem over more than a decade of development has been solved under deterministic conditions. This paper proposes a model to find the optimal transit priority scheme in a multimodal transportation network under uncertain demand. This model is formulated as a risk-based bi-level optimization problem. At the upper-level, a risk measure of expected social cost is minimized subject to a chance constraint on total travel time with a user-specified confidence level and a budget constraint. At the lower-level, a mode choice, a traffic user equilibrium assignment, and a transit assignment are applied.

An ant colony algorithm is utilized to solve this complex design problem. Numerical results using a real world middle-size city network empirically demonstrate that the demand uncertainty has a significant impact on the solution and the proposed model is applicable to realistic networks.

191. Passenger Behavior Simulation in Congested Urban Rail Transit System: A Capacity-Limited Optimal Strategy Model for Passenger Assignment

1. Lu, Kai; Cao, Nan
2. COMPLEXITY

Optimal strategy, one of the main transit assignment models, can better demonstrate the flexibility for passengers using routes in a transit network. According to the basic optimal strategy model, passengers can board trains based on their frequency without any capacity limitation. In the metropolitan cities such as Beijing, Shanghai, and Hong Kong, morning commuters face huge transit problems. Especially for the metro system, there is heavy rush in metro stations. Owing to the limited train capacity, some passengers cannot board the first coming train and need to wait for the next one. To better demonstrate the behavior of passengers pertaining to the limited train capacity, we consider capacity constraints for the basic optimal strategy model to represent the real situation. We have proposed a simulation-based algorithm to solve the model and apply it to the Beijing Subway to demonstrate the feasibility of the model. The application of the proposed approach has been demonstrated using the computational results for transit networks originating from practice.

192. Consideration of different travel strategies and choice set sizes in transit path choice modelling

1. Hassan, Mohammad Nurul; Rashidi, Taha Hossein; Nassir, Neema
2. TRANSPORTATION

Path choice modelling is typically conducted by considering a subset of paths, not the universal set of all feasible paths as this is computationally challenging. This study proposes a two-stage modelling approach. In the first stage, it develops a new probabilistic importance sampling protocol by using fuzzy logic. In the second stage, it tested different structures of the discrete choice models, where different strategy attributes are considered along with the traditional variables. The results prove that the new sampling protocol performs better than traditional sampling protocol. Again, the inclusion of the strategy attributes proves to yield better prediction. The results of the study recommend considering different strategy attributes in the path generation process as well as in the transit assignment models. The study also discusses the effect of the choice set size on the model performance. Household travel survey data of south-east Queensland, Australia is used to develop the models.

193. A modelling platform for optimizing time-dependent transit fares in large-scale multimodal networks

1. Kamel, Islam; Shalaby, Amer; Abdulhai, Baher
2. TRANSPORT POLICY

With the continuous growth of urban areas around the world, overcrowding in large transit networks has become a persistent problem, with far-reaching impacts similar to those caused by congestion in large road networks. Moreover, instead of serving as a relief for large transportation systems,

congested transit networks have increased delay-related traffic and transit costs. In light of these problems, cities seek cost-effective and relatively fast-to-implement strategies to mitigate transit system congestion, one of which is time-based fare structures. By implementing time-based fares, the transit demand may shift out of the congested peak periods, easing transit travel conditions. Although time-based fares are already in use in some transportation systems, their implementation is usually based on simplified what-if analyses. Such analyses of fare structures in previous studies have lacked a comprehensive evaluation of people's responses to these fares and is usually applied to simple or sometimes hypothetical transportation networks. Therefore, this paper presents a platform for analyzing and optimizing time-based transit fares in large networks, taking into consideration the effects of these fares on people's choices of mode, departure time, and route in addition to the interactions between transit vehicles and general traffic. As a case study, the largest metropolitan area in Canada, the Greater Toronto Area, is tested. The results show that the optimal time-based fares help spread the transit demand to the shoulders of the peak. However, the savings in weighted average multimodal door-to-door travel time over the whole network are slightly small compared to the large increase in peak-hour fares.

194. Schedule-based dynamic assignment models for public transport networks

1. Russo, F

2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

In the sphere of transit assignment, the dynamic models approach is the focus of increasing interest, because of the importance of explicit system simulations to know user flow for each run and the performance of different service networks in terms of times and comfort levels, and to enable user decisions to be evaluated if ITS is used. Urban transit systems are characterised not only by day-to-day dynamics but also within-day dynamics. Thus the evaluation process has to be represented by means of the two relative processes (within-day and day-to-day). This paper reports some extension and review on the framework of the approach proposed by Nuzzolo and Russo (1998) and generalized in Nuzzolo et al. (2001, 2002), with the study of the different aspects of path choice - on the demand side - and of operating services - on the supply side - in relation to the different assignment models that can be useful.

195. Dynamic Assignment-Simulation Methodology for Multimodal Urban Transit Networks

1. Verbas, I. Oemer; Mahmassani, Hani S.; Hyland, Michael F.

2. TRANSPORTATION RESEARCH RECORD

This paper presents an integrated transit assignment-simulation tool. Finding least cost hyperpaths in a large-scale network and assigning travelers onto these paths are computationally challenging problems. Moreover, modeling the spatial and temporal complexities in a transit network that result from the discontinuities in transit events, such as missing a connection and not receiving a seat, exacerbates the issue of capturing realism. These challenges are overcome by (a) using a least cost hyperpath algorithm that captures the multimodal, multipattern, time-, and approach-dependent features of a transit network to provide realistic optimal strategies; (b) using a gap-based assignment approach to reach fast convergence; and (c) developing a multiagent particle simulation platform that is able to capture the heterogeneities and the discontinuities in travel. The platform was tested on the Chicago Transit Authority network of 14,000 nodes and 64,000 links; 1.25 million travelers were

assigned and simulated, along with 21,000 transit vehicles. The assignment-simulation framework can be used as a network evaluation tool to assist decision making at the strategic and operational levels.

196. Policy-Combination Oriented Optimization for Public Transportation Based on the Game Theory

1. Zhu, Wentao; Chen, Mengwei; Wang, Dianhai; Ma, Dongfang
2. MATHEMATICAL PROBLEMS IN ENGINEERING

This research aims at detecting the interactions between policy maker and travelers when making public transport policy and strategies to optimize relevant policy combination. In the two scenarios of whether to set a bus lane or not, travel cost functions of bus and car are proposed, respectively, with the in-vehicle comfort level of passengers considered. By introducing the bottleneck model and transit assignment model, travelers' behaviors are revealed according to different travel mode. Focusing on minimizing the total cost of the system (TSC), Stackelberg game model is built to describe the dynamic interactions between the government, the bus company, and travelers. Finally, kriging surrogate method is proposed on account of numerical simulation to find solution to the game model and propose the optimal policy combination and resource allocation. The results show an effective performance: under the assumption that the travel distance is 20km, the optimized policy combination can reduce TSC by 8.59% and 9.82% in two scenarios, respectively, and reduce travel cost per person by 10.28% and 15.85%, respectively.

197. Schedule-based path-finding algorithms for transit trip-planning systems

1. Huang, RH; Peng, ZR
2. TRANSPORTATION NETWORK MODELING 2002: PLANNING AND ADMINISTRATION

Many existing methods for transit assignment and path finding do not support schedule coordination in network search or optimization processes. Other methods do not provide adequate performance that meets the demands for Internet trip-planning applications. Two schedule-based path-finding algorithms (forward search and backward search) are presented for the transit network, in which schedule coordination is an inherent feature. The forward-search algorithm finds the optimal path from an origin to a destination with a planned departure time, and the backward-search algorithm finds the optimal path for an expected arrival time at the destination. In addition, a non-schedule-based minimal-transfer-path algorithm for the transit network is also developed, which is capable of accommodating more path optimization criteria for sophisticated path finding. Facilitated by a uniquely designed network structure based on a geographic information system and an object-oriented data model, these algorithms demonstrated good performance in path finding on a dynamic transit network. These algorithms have been implemented in an Internet transit trip-planning system in the city of Waukesha, Wisconsin.

198. Generation and calibration of transit hyperpaths

1. Schmoecker, Jan-Dirk; Shimamoto, Hiroshi; Kurauchi, Fumitaka
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper introduces a new discrete choice model aimed at describing behaviour of public transport passengers at stops. We assume that passengers choose a set of buses from which they take the first arriving. This leads to a nested model formulation in which the upper level (choice set formation) is

based on utility maximisation. The lower level choice of a specific bus from the choice set is given by the frequency distribution of the bus arrivals. We further consider hyperpath characteristics in the choice set formulation which means that the utility of the choice set in general increases with the addition of further options due to a reduction in the reduced waiting time. We discuss model properties and apply our model to some selected OD pairs of the bus network of a local city in Japan where we could observe passenger behaviour due to the availability of smart card data. We find that choice sets vary fairly significantly between some passenger groups and discuss implications for transit assignment models. (C) 2013 Elsevier Ltd. All rights reserved.

199. The generalized Nash equilibrium model for oligopolistic transit market with elastic demand

1. Zhou, J; Lam, WHK; Heydecker, BG
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper presents a bilevel transit fare equilibrium model for a deregulated transit system. In the upper-level problem, the transit competition is portrayed as an n-player, non-cooperative game by changing the fare structure of each of a set of transit lines separately so as to maximize the profit of each transit operator within the oligopolistic market. We show that there exists a generalized Nash game between transit operators, which can be formulated as a quasi-variational inequality problem. In the lower-level problem, the passengers' response to the equilibrium fare structure of the transit operators is represented by the stochastic user equilibrium transit assignment model with elastic OD demand. As a result, the bilevel transit fare equilibrium problem is presented in the Stackelberg form and solved by a heuristic solution algorithm based on a sensitivity analysis approach. A numerical example is given to illustrate the competition mechanism on the transit network and some useful findings are presented on competitive operations. (c) 2004 Elsevier Ltd. All rights reserved.

200. Intermodal Path Algorithm for Time-Dependent Auto Network and Scheduled Transit Service

1. Khani, Alireza; Lee, Sanggu; Hickman, Mark; Noh, Hyunsoo; Nassir, Neema
2. TRANSPORTATION RESEARCH RECORD

A simple but efficient algorithm is proposed for finding the optimal path in an intermodal urban transportation network. The network is a general transportation network with multiple modes (auto, bus, rail, walk, etc.) divided into the two major categories of private and public, with proper transfer constraints. The goal was to find the optimal path according to the generalized cost, including private-side travel cost, public-side travel cost, and transfer cost. A detailed network model of transfers between modes was used to improve the accounting of travel times during these transfers. The intermodal path algorithm was a sequential application of specific cases of transit and auto shortest paths and resulted in the optimal intermodal path, with the optimal park-and-ride location for transferring from private to public modes. The computational complexity of the algorithm was shown to be a significant improvement over existing algorithms. The algorithm was applied to a real network within a dynamic traffic and transit assignment procedure and integrated with a sequential activity choice model.

201. Variability of commuters' bus line choice: an analysis of oyster card data

1. Kurauchi, Fumitaka; Schmoecker, Jan-Dirk; Shimamoto, Hiroshi; Hassan, Seham M.

2. PUBLIC TRANSPORT

A hyperpath can be defined as a set of attractive lines identified by the passenger, each of which might be the optimal one from the current stop, depending on lines' arrival time, frequency, cost etc. This concept can lead to complex route choice and has been a fundamental assumption in most transit assignment models, despite few evidence whether passengers' indeed select such complex strategies. This research uses time series smart card data from London to investigate flexibility in buses chosen by morning commuters. The analysis is based on n-step Markov models and proposes that the variations in bus lines taken by passengers who supposedly travel between the same OD pair every morning over several days should reflect the set of paths included in an (optimal) hyperpath. Our hypothesis is that a large variation in bus lines over days indicates a complex hyperpath whereas a passenger who takes the same line every morning does not consider many alternatives. Our results suggest that there is indeed significant variation in bus lines chosen, possibly in accordance with the theory of hyperpaths in networks with uncertainty.

202. Generation and Calibration of Transit Hyperpaths

1. Schmoecker, Jan-Dirk; Shimamoto, Hiroshi; Kurauchi, Fumitaka
2. 20TH INTERNATIONAL SYMPOSIUM ON TRANSPORTATION AND TRAFFIC THEORY (ISTTT 2013)

This paper introduces a new discrete choice model aimed at describing behaviour of public transport passengers at stops. We assume that passengers choose a set of buses from which they take the first arriving. This leads to a nested model formulation in which the upper level (choice set formation) is based on utility maximization. The lower level choice of a specific bus from the choice set is given by the frequency distribution of the bus arrivals. We further consider hyperpath characteristics in the choice set formulation which means that the utility of the choice set in general increases with the addition of further options due to a reduction in the reduced waiting time. We discuss model properties and apply our model to some selected OD pairs of the bus network of a local city in Japan where we could observe passenger behaviour due to the availability of smart card data. We find that choice sets vary fairly significantly between some passenger groups and discuss implications for transit assignment models. (C) 2013 The Authors. Published by Elsevier Ltd.

203. FREQUENCY-BASED AND SCHEDULE-BASED TRANSIT MODELING APPROACHES: CURRENT STATE, ACHIEVEMENTS AND CHALLENGES

1. Poon, M. H.; Tong, C. O.; Wong, S. C.
2. TRANSPORTATION STUDIES: SUSTAINABLE TRANSPORTATION, PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES

The interest in transit path choice and assignment models stems from the need to determine or simulate link flows on transportation networks. The models together with the network performance characteristics are usually used as basic tools for the planning and design of infrastructure and public transport services. Transport planners and transit operators can also use the models to test the impact of various transportation policies, such as changes in vehicle schedules, or flexible work start time. The transit assignment problem has been studied by a number of researchers and various models have been proposed in the past. Those models can be broadly divided into two different approaches, namely frequency-based and schedule-based approaches, in accordance with the method of describing the transit network attributes. The purpose of this paper is to give an overview about the

state of the art in research on these two different transit modeling approaches; comment on the achievements, challenges and limitations of the models; and discuss some future research directions for these two approaches.

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

1. Nielsen, OA

2. SCHEDULE-BASED DYNAMIC TRANSIT MODELING: THEORY AND APPLICATIONS

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.

205. 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-TRANSPORT DYNAMICS

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.

206. Empirical Analysis of Traveling Backwards and Passenger Flows Reassignment on a Metro Network with Automatic Fare Collection (AFC) Data and Train Diagram

1. Xu, Ruihua; Li, Yanan; Zhu, Wei; Li, Sijie

2. TRANSPORTATION RESEARCH RECORD

Metro (subway) systems are becoming overcrowded in some of China's mega-cities, such as Beijing, Shanghai, and Guangzhou. As many passengers are unable to board trains on an overcrowded metro network during peak periods, some of them are willing to spend more time and energy by traveling backwards in order to secure a seat or even room for standing. Traditional studies on travel behavior analysis and transit assignment models seldom deal with this situation. We propose a methodology including the affinity propagation cluster method with between-within-proportion (BWP) index and an adaptive 0-1 model named the traveling backwards model (TBM) to identify the phenomenon of traveling backwards and to reassign passenger flows on a metro network using automatic fare collection (AFC) data and actual train diagrams. As a numerical example, this integrated approach is applied to the Beijing metro system. Our research shows that the affinity propagation cluster method with BWP index and implicit enumeration algorithm for TBM work well. TBM is a good replacement for the existing assignment model and travel behavior analysis, especially for those mega-cities' networks in peak hours.

207. Deep-Learning Architectures to Forecast Bus Ridership at the Stop and Stop-To-Stop Levels for Dense and Crowded Bus Networks

1. Baek, Junghan; Sohn, Keemin
2. APPLIED ARTIFICIAL INTELLIGENCE

The conventional transit assignment models that depend on either probabilistic or deterministic theory have failed to accurately estimate rider demand for dense and crowded bus transit networks. It is well known that the existing models are so blunt that they cannot accommodate the impact of miscellaneous changes in activity and transportation systems on bus demand. Recently, artificial neural networks (ANNs) have been refocused after two monumental breakthroughs: Big-data and a novel pre-training method. A deep-learning model, which simply represents an ANN with multiple hidden layers, has had a great success in recognizing images, human voices, and handwritten texts. The present study adopted a deep-learning model to forecast bus ridership at the stop and stop-to-stop levels. While the stop-level model, which had insufficient training data, suffered from an overfitting of the data, the stop-to-stop-level model showed good performance both in training and testing. The success of the latter model is owed to a larger sample size compared with the former model. This represents the first meaningful attempt to apply a data-driven approach to forecasting transportation demand.

208. Stochastic transit equilibrium

1. Cortes, Cristian E.; Jara-Moroni, Pedro; Moreno, Eduardo; Pineda, Cristobal
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

We present a transit equilibrium model in which boarding decisions are stochastic. The model incorporates congestion, reflected in higher waiting times at bus stops and increasing in-vehicle travel time. The stochastic behavior of passengers is introduced through a probability for passengers to choose boarding a specific bus of a certain service. The modeling approach generates a stochastic common-lines problem, in which every line has a chance to be chosen by each passenger. The formulation is a generalization of deterministic transit assignment models where passengers are assumed to travel according to shortest hyperpaths. We prove existence of equilibrium in the simplified case of parallel lines (stochastic common-lines problem) and provide a formulation for a more general

network problem (stochastic transit equilibrium). The resulting waiting time and network load expressions are validated through simulation. An algorithm to solve the general stochastic transit equilibrium is proposed and applied to a sample network; the algorithm works well and generates consistent results when considering the stochastic nature of the decisions, which motivates the implementation of the methodology on a real-size network case as the next step of this research. (C) 2013 Elsevier Ltd. All rights reserved.

209. Should Optimal Stop Spacing Vary by Land Use Type? New Methodology

1. Chen, Jingxu; Currie, Graham; Wang, Wei; Liu, Zhiyuan; Li, Zhibin
2. TRANSPORTATION RESEARCH RECORD

This study aimed to establish whether optimal stop spacing should vary by land use type. A new stop clustering method was proposed with stops divided into catchments on the basis of land use. A bilevel optimization model was then used to suggest optimal stop spacing for these catchments. The upper-level problem minimized a cost function that represented the perspectives of the passengers, the operators, and the local authority, and the lower-level problem was the transit assignment problem. Results show that stop spacing in the catchments with residential usage is generally larger than in those catchments with nonresidential or mixed land use. Near-optimal solutions were proposed to accommodate local considerations of stop placement. The spacing interval created by near-optimal solutions could be used to adjust existing stop placement. A case study of Tram Route 109 in Melbourne, Australia, revealed that the practical implication of the proposed analytical approach indeed improved the practical operations of the tram service. In future studies, the model could be extended to a network of tram routes. Overall, the results suggest that optimal stop spacing on public transport should be a function of land use type.

210. Validating the passenger traffic model for copenhagen

1. Vuk, Goran; Hansen, Christian Overgaard
2. TRANSPORTATION

The paper presents a comprehensive validation procedure for the passenger traffic model for Copenhagen based on external data from the Danish national travel survey and traffic counts. The model was validated for the years 2000-2004, with 2004 being of particular interest because the Copenhagen Metro became operational in autumn 2002. We observed that forecasts from the demand sub-models agree well with the data from the 2000 national travel survey, with the mode choice forecasts in particular being a good match with the observed modal split. The results of the 2000 car assignment model matched the observed traffic better than those of the transit assignment model. With respect to the metro forecasts, the model over-predicts metro passenger flows by 10-50%. The wide range of findings from the project resulted in two actions. First, a project was started in January 2005 to upgrade the model's base trip matrices. Second, a dialog between researchers and the Ministry of Transport has been initiated to discuss the need to upgrade the Copenhagen model, e.g. a switching to an activity-based paradigm and improving assignment procedures.

211. On passenger traffic along a transit line: a stochastic model of station waiting and in-vehicle crowding under distributed headways

1. Leurent, Fabien; Pivano, Cyril; Poulhes, Alexis
2. 20TH EURO WORKING GROUP ON TRANSPORTATION MEETING, EWGT 2017

Traffic along a transit line involves two kinds of mobile entities: passengers versus vehicles. The paper develops a stochastic model to deal with: headways between successive runs serving stations, wait times at boarding stations, passenger flows per vehicle and by leg (i.e. pair of entry-exit stations), in-vehicle comfort differentiating between seated and standing places. While previous static models of transit assignment consider vehicle passenger flows that are averaged over the vehicle runs, we model distributed headways, thus taking into account the issues of regularity and reliability. The Rank conservation postulate of Leurent et al. (2012a, b) is used to establish analytical formulae for the expectation and variance of every traffic variable of interest: leg flows, link flows, wait times, leg physical times, generalized times at waiting and in-vehicle. The linkage between waiting prior to boarding and in-vehicle crowding is modeled: each user is concerned individually, conditionally to the headway during which he waits for the vehicle. A computation scheme is provided to deliver the statistical summaries of the array of traffic variables. (C) 2017 The Authors. Published by Elsevier B.V.

212. Estimation of Transfer Time Distribution Parameters with Automatic Fare Collection Data: Stochastic Frontier Model

1. Wahaballa, Amr M.; Kurauchi, Fumitaka; Schmoecker, Jan-Dirk; Iwamoto, Takenori
2. JOURNAL OF TRANSPORTATION ENGINEERING PART A-SYSTEMS

The uncertainty in walking and waiting transfer times at transit stops depends on the environmental conditions, vehicle schedule punctuality, and variations among individuals. Relying only on the mean values ignores such uncertainty and leads to improper transfer coordination. This paper provides a general framework to estimate the time distribution parameters of walking and waiting based on automatic-fare-collection data under the assumption that the distribution function is known. The proposed methodology contributes to the existing literature by providing a stochastic frontier model (SFM) that is adaptable to transit assignment models. The normal/exponential SFM is utilized to estimate distribution parameters based on the maximum-likelihood method. The methodology was applied to smart-card data from Japan to estimate the transfer walking- and waiting-time distributions between bus stops and rail stations. The results indicate a low disturbance in the observed data for walking time and that our assumptions regarding walking-time estimation were reliable. Furthermore, we quantified how the waiting time at a bus stop depends on variations in the service headway. These findings are expected to help in making more informed decisions to optimize transit schedules.

213. Discovering the Hidden Community Structure of Public Transportation Networks

1. Hajdu, Laszlo; Bota, Andras; Kresz, Miklos; Khani, Alireza; Gardner, Lauren M.
2. NETWORKS & SPATIAL ECONOMICS

Advances in public transit modeling and smart card technologies can reveal detailed contact patterns of passengers. A natural way to represent such contact patterns is in the form of networks. In this paper we utilize known contact patterns from a public transit assignment model in a major metropolitan city, and propose the development of two novel network structures, each of which elucidate certain aspects of passenger travel behavior. We first propose the development of a transfer network, which can reveal passenger groups that travel together on a given day. Second, we propose the development of a community network, which is derived from the transfer network, and captures the similarity of travel patterns among passengers. We then explore the application of each of these network structures to identify the most frequently used travel paths, i.e., routes and transfers, in the public transit system, and model epidemic spreading risk among passengers of a public transit

network, respectively. In the latter our conclusions reinforce previous observations, that routes crossing or connecting to the city center in the morning and afternoon peak hours are the most dangerous during an outbreak.

214. Optimizing Bus Frequencies under Uncertain Demand: Case Study of the Transit Network in a Developing City

1. Huang, Zhengfeng; Ren, Gang; Liu, Haixu
2. MATHEMATICAL PROBLEMS IN ENGINEERING

Various factors can make predicting bus passenger demand uncertain. In this study, a bilevel programming model for optimizing bus frequencies based on uncertain bus passenger demand is formulated. There are two terms constituting the upper-level objective. The first is transit network cost, consisting of the passengers' expected travel time and operating costs, and the second is transit network robustness performance, indicated by the variance in passenger travel time. The second term reflects the risk aversion of decision maker, and it can make the most uncertain demand be met by the bus operation with the optimal transit frequency. With transit link's proportional flow eigenvalues (mean and covariance) obtained from the lower-level model, the upper-level objective is formulated by the analytical method. In the lower-level model, the above two eigenvalues are calculated by analyzing the propagation of mean transit trips and their variation in the optimal strategy transit assignment process. The genetic algorithm (GA) used to solve the model is tested in an example network. Finally, the model is applied to determining optimal bus frequencies in the city of Liupanshui, China. The total cost of the transit system in Liupanshui can be reduced by about 6% via this method.

215. A GLOBAL CONTAINER FLOW MODEL

1. Bell, M. G. H.; Liu, X.; Hosseinloo, S. H.; Angeloudis, P.
2. TRANSPORTATION AND URBAN SUSTAINABILITY

This paper transfers the classic frequency-based transit assignment method of Spiess and Florian to containers demonstrating its promise as the basis for a global maritime container assignment model. In this model, containers are carried by shipping lines operating strings (or port rotations) with given service frequencies. An origin-destination matrix of full containers is assigned to these strings to minimize sailing time plus container dwell time at the origin port and any intermediate transshipment ports. This necessitated two significant model extensions. The first involves the repositioning of empty containers so that a net outflow of full containers from any port is balanced by a net inflow of empty containers, and vice versa. As with full containers, empty containers are repositioned to minimize the sum of sailing and container dwell time, with a facility to discount the dwell time of empty containers in recognition of the absence of inventory. The second involves the inclusion of port and route capacity constraints. The dual variables for these constraints provide estimates of container handling and route surcharges. Insight into the interpretation of the dual variables is given in the paper by proposition and proof. The properties of the model are illustrated by a number of numerical examples. The paper concludes by considering the next steps in model development.

216. Calibrating travel time thresholds with cluster analysis and AFC data for passenger reasonable route generation on an urban rail transit network

1. Zhu, Wei; Fan, Wei-li; Wahaballa, Amr M.; Wei, Jin
2. TRANSPORTATION

Estimating the route choice patterns for transit passengers is important to improve service reliability. The size and composition of a route choice set affects the choice model estimation and passenger flow calculations for urban rail transit (URT) networks. With the existing threshold decision method, there will be omissions or excess routes in the generated route set, which lead to a significant deviation in passenger flow assignments. This paper proposes a data-driven approach to calibrate the travel time thresholds when generating reasonable route choice sets. First, an automatic fare collection (AFC) data-driven framework is established to more accurately calibrate and dynamically update travel time thresholds with changes in the URT system. The framework consists of four steps: data preprocessing, origin-destination-based threshold calculation, cluster analysis-based calibration, and calibrated result output and update. Second, the proposed approach is applied to the Beijing subway as a case study, and several promising results are analyzed that allow the optimization of existing travel time thresholds. The obtained results help in the estimation of route choice behavior to validate current rail transit assignment models. This study is also applicable for other rail transit networks with AFC systems to record passenger passage times at both entry and exit gates.

217. WALK MODELLING WHEN DESIGNING SMALL BUS TRANSIT NETWORKS

1. Husselmann, G.; van Vuuren, J. H.; Andersen, S. J.
2. SOUTH AFRICAN JOURNAL OF INDUSTRIAL ENGINEERING

Models for the design of public bus transit networks are usually based on the historically observed origin-demand travel patterns of potential passengers. The option of a passenger choosing to walk is, however, not usually incorporated into the design models for such networks. We argue that the absence of this model feature might lead to significant sub-optimality, especially in the design of small public bus transit networks. A novel approach to including this feature in the bus frequency setting aspect of public bus transit network design models is demonstrated in this paper, in which passenger transit modal choices are modelled on the basis of an existing optimal strategy transit assignment model. The newly proposed bi-objective route design and frequency setting models are applied to a realistic case study involving the establishment of a public bus transit system for students on a university campus; and this model implementation is used to gain insight into passenger route choice behaviour, based on individual preferences between walking or using buses. It is shown in the context of this case study that including the option of a passenger walking in the design models for public bus transit networks can affect the efficacy of the final network, especially if the network is small.

218. Estimation of Platform Waiting Time Distribution Considering Service Reliability Based on Smart Card Data and Performance Reports

1. Wahaballa, Amr M.; Kurauchi, Fumitaka; Yamamoto, Toshiyuki; Schmocker, Jan-Dirk
2. TRANSPORTATION RESEARCH RECORD

The estimation of platform waiting time has so far received little attention. This research aimed to estimate platform waiting time distributions on the London Underground, considering travel time variability by using smart card data that were supplemented by performance reports. The on-train and ticket gate to platform walking times were assumed to be normally distributed and were matched with the trip time recorded by the smart cards to estimate the platform waiting time distribution. The stochastic frontier model was used, and its parameters were estimated by the maximum likelihood method. The cost frontier function was used to represent the relation between the travel time recorded in the smart card data as an output and the on-train time and walking time between the ticket gate

and the platform as inputs. All estimated parameters were statistically significant, as shown by p-values. Comparing the travel time values estimated by the proposed model with the times recorded in the smart card data shows a goodness-of-fit coefficient of determination of more than 95%. The estimation proved to have quick convergence and was computationally efficient. The results could facilitate improvements in transit service reliability analysis and passenger flow assignment. Matching the obtained distributions with the observed smart card data will help with estimating route choice behavior that can validate current transit assignment models.

219. Using connectivity for measuring equity in transit provision

1. Kaplan, Sigal; Popoks, Dmitrijs; Prato, Carlo Giacomo; Ceder, Avishai (Avi)
2. JOURNAL OF TRANSPORT GEOGRAPHY

This study proposes the assessment of equity in transit provision by using transit connectivity as a comprehensive impedance measure. Transit connectivity considers in-vehicle time, access/egress times, waiting time, service reliability, frequency, and 'seamless' transfers along multi-modal paths. In addition, transit connectivity weighs the impedance components according to their relative importance to travelers. The assessment of equity was performed for the multi-modal transit system in the Greater Copenhagen Area, renowned for its transit-oriented finger-plan. The assessment method used a GIS representation of the network (i.e., service lines, timetables, metro stations, train stations, and bus stops), and transit assignment results (i.e., level-of-service times, passenger flows). The assessment method proved effective in calculating location-based and potential-accessibility measures and Gini coefficients of inequality in the Greater Copenhagen Area. Results show that the transit-oriented development contributes to spatial equity with high connectivity in densely populated zones, vertical equity with comparable connectivity in high income and low income zones, inter-generational equity with good connectivity provision for students to higher-education and job opportunities. Also, results show that the north-west 'finger' is less equitable with lower connectivity for low population density and lower connectivity to higher-education opportunities regardless of the high number of students. (C) 2014 Elsevier Ltd. All rights reserved.

220. Reducing passengers' travel time by optimising stopping patterns in a large-scale network: A case-study in the Copenhagen Region

1. Parbo, Jens; Nielsen, Otto A.; Prato, Carlo G.
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

Optimising stopping patterns in railway schedules is a cost-effective way to reduce passengers' generalised travel costs without increasing train operators' costs. The challenge consists in striking a balance between an increase in waiting time for passengers at skipped stations and a decrease in travel time for through-going passengers, with possible consequent changes in the passenger demand and route choices. This study presents the formulation of the skip-stop problem as a bi-level optimisation problem where the lower level is a schedule-based transit assignment model that delivers passengers' route choices to the skip-stop optimisation model at the upper level, and where the upper level in return provides an improved timetable to the lower level. A heuristic method for large-scale urban networks is presented to solve this extremely complex bi-level problem, where the skip-stop optimisation is a mixed-integer problem, whereas the route choice model is a non-linear non-continuous mapping of the timetable. The method was tested on the suburban railway network in the Greater Copenhagen Region (Denmark): the reduction in railway passengers' in-vehicle travel time was

5.5%, the reduction in passengers' generalised travel cost was 3.2% and, at the system level, the yearly consumer surplus amounted at 76.7 million DKK (about 10.3 million EUR or 12.7 million USD) when compared to the existing stopping patterns.

221. Integrated Multimodel Evaluation of Transit Bus Emissions in Toronto, Canada

1. Lau, Judith; Hatzopoulou, Marianne; Wahba, Mohamed M.; Miller, Eric J.
2. TRANSPORTATION RESEARCH RECORD

This paper investigates transit bus emissions in the city of Toronto, Ontario, Canada, by linking the results of a microsimulation transit assignment model, MILATRAS (microsimulation learning-based approach to transit assignment), with emission factors derived from Mobile6.2C. Emissions were estimated at the level of individual buses during idling conditions at bus stops and on roadway links between stops during the morning peak period. The busiest routes were associated with the highest total emissions as a result of a combination of high ridership and lower speeds; this association confirmed the common wisdom that newer, low-emitting buses should be first allocated to these routes. The highest dwell emissions occurred at intermodal transfer stations (bus to subway and vice versa). On a passenger kilometer basis, the highest-emitting routes were not the busiest, but rather were those with the lowest ridership. In fact, the highest emissions per passenger kilometer were associated with the Airport Rocket, a route that provided service to the airport and was characterized by low ridership in the morning peak period. On average, bus trips in Toronto were about three times more fuel efficient than were private car trips and created 20 times less carbon monoxide pollution. The effects of changing fuel types and fleet age on transit bus emissions were assessed. Implications for bus operations are discussed relative to fleet allocation to minimize total emissions.

222. Evaluating skip-stop policy in urban rail transit systems based on passenger cost

1. Peftitsi, Soumela; Jenelius, Erik; Cats, Oded
2. JOURNAL OF PUBLIC TRANSPORTATION

Increasing the operating speed in public transport systems can increase the system capacity, reduce the overall passenger travel time and improve experienced comfort. Skip-stop operation, where subsets of the trains operating on the same tracks skip certain intermediate stops, can accelerate the service and improve passengers' overall travel experience. This paper considers the problem of deciding whether skip-stop operation is beneficial for a given line and which stopping scheme is the most effective. In particular, we investigate whether a simple decision rule for determining the stopping pattern under a skip-stop strategy, derived from the expected weighted time benefits to the passengers, can reliably determine the most suitable skip-stop scheme. To evaluate the impact of alternative stop-skipping strategies, we adopt the existing public transit assignment model Bus - Mezzo, which allows for a realistic representation of passengers' experienced waiting and in-vehicle travel times and the resulting trade-offs between passenger costs and benefits. The decision rule is applied to a set of high-frequency urban rail lines in Stockholm, Sweden. We show that a simple decision rule may not be a robust way of determining a beneficial skip-stop scheme. The results from the case study reveal that the skip-stop operation can have an overall positive impact on passenger generalized travel time but only under certain conditions at the stops along the line.

223. Optimization of Transit Priority in the Transportation Network Using a Genetic Algorithm

1. Mesbah, Mahmoud; Sarvi, Majid; Currie, Graham

2. IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS

This paper proposes a detailed formulation to optimize transit road space priority at the network level and utilizes an efficient heuristic method to find the optimum solution. Previous approaches to transit priority have a localized focus in which only limited combinations of transit exclusive lanes could be assessed. The aim of this work is to reallocate the road space between private car and transit modes so that the system is optimized. A bilevel programming approach is adapted for this purpose. The upper level involves an objective function from the system managers' perspective, whereas at the lower level, a users' perspective is modeled. To take into account the major effects of a priority provision, three models are used: 1) a modal split; 2) a user equilibrium traffic assignment; and 3) a transit assignment. A genetic algorithm (GA) approach is used, which enables the method to be applied to large networks. Application of a parallel GA is also demonstrated in the solution method, which has a considerably shorter execution time. The methodology is applied to an example network, and results are discussed. It is found that the proposed methodology can successfully consider benefits of all stakeholders in the introduction of transit lanes. Furthermore, using parallel GA enables the methodology to be used for real-world-network scale in a shorter computer processing time.

224. Transit route and frequency design: Bi-level modeling and hybrid artificial bee colony algorithm approach

1. Szeto, W. Y.; Jiang, Y.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper proposes a bi-level transit network design problem where the transit routes and frequency settings are determined simultaneously. The upper-level problem is formulated as a mixed integer non-linear program with the objective of minimizing the number of passenger transfers, and the lower-level problem is the transit assignment problem with capacity constraints. A hybrid artificial bee colony (ABC) algorithm is developed to solve the bi-level problem. This algorithm relies on the ABC algorithm to design route structures and a proposed descent direction search method to determine an optimal frequency setting for a given route structure. The descent direction search method is developed by analyzing the optimality conditions of the lower-level problem and using the relationship between the lower- and upper-level objective functions. The step size for updating the frequency setting is determined by solving a linear integer program. To efficiently repair route structures, a node insertion and deletion strategy is proposed based on the average passenger demand for the direct services concerned. To increase the computation speed, a lower bound of the objective value for each route design solution is derived and used in the fitness evaluation of the proposed algorithm. Various experiments are set up to demonstrate the performance of our proposed algorithm and the properties of the problem. (C) 2014 Elsevier Ltd. All rights reserved.

225. Policy-Making Tool for Optimization of Transit Priority Lanes in Urban Network

1. Mesbah, Mahmoud; Sarvi, Majid; Currie, Graham; Saffarzadeh, Mahmoud
2. TRANSPORTATION RESEARCH RECORD

Transit improvement is an effective way to relieve traffic congestion and decrease greenhouse gas emissions. Improvement can be in the form of new facilities or giving on-road priority to transit. Although construction of off-road mass transit is not always viable, giving priority to transit can be a low-cost alternative. A framework is introduced for optimization of bus priority at the network level.

The framework identifies links on which a bus lane should be located. Allocation of a lane to transit vehicles would increase the utility of transit, although this can be a disadvantage to auto traffic. The approach balances the impact on all stakeholders. Automobile advocates would like to increase traffic road space, and the total travel time of users and total emissions of the network could be reduced by a stronger priority scheme. A bilevel optimization is applied that encompasses an objective function at the upper level and a mode choice, a traffic assignment, and a transit assignment model at the lower level. The proposed optimization helps transport authorities to quantify the outcomes of various strategies of transit priority. A detailed sensitivity analysis is carried out on the relative weight of each factor in the objective function. The proposed framework can also be applied in the context of high-occupancy-vehicle lanes and heavy-vehicle priority lanes.

226. Transit Path Building To Multipath or Not to Multipath

1. Kurth, David L.; Childress, Suzanne; Sabina, Erik; Ande, Sreekanth; Cryer, Lee
2. TRANSPORTATION RESEARCH RECORD

Two basic options exist for modeling transit path choice in the travel forecasting process: (a) a detailed mode choice model and (b) deterministic procedures underlying transit multipath, path-building algorithms. These two options require different approaches to transit path building, mode choice, and transit assignment. Modeling decisions regarding transit path-building techniques and the amount of transit path choice incorporated into mode choice models directly affect the ability of travel models to consistently model mode choice and transit use. Options and their implications are presented for transit path building and mode choice. An analysis is presented of the success of alternate transit path-building techniques in reproducing known transit paths as reported by transit users in Denver, Colorado; analysis of several commonly used transit path-building validation techniques is also given. Suggestions are made for interface transit path choice and transit path building on the basis of the results of the empirical transit path-building tests. Two primary suggestions applicable to current planning processes are made. First, transit path choice should be performed in only one component of the forecasting process, such as transit path building or mode choice, to minimize inconsistencies in the modeling process. Second, disaggregate measures such as prediction success tables comparing modeled boardings to reported boardings for individual observations of transit trips should be compiled for validation of transit networks and transit path-building procedures.

227. Estimation of Denied Boarding in Urban Rail Systems: Alternative Formulations and Comparative Analysis

1. Ma, Zhenliang; Koutsopoulos, Haris N.; Chen, Yunqing; Wilson, Nigel H. M.
2. TRANSPORTATION RESEARCH RECORD

Monitoring rail transit system performance is important for effective operations planning. The number of times passengers are denied boarding is becoming a key measure of the impact of near-capacity operations on customers and is fundamental for calculating other performance metrics, such as expected waiting time for service. This paper reviews existing methods and proposes a denied boarding probability distribution inference method for closed Automated Fare Collection (AFC) urban rail systems. Using AFC (tap-in and tap-out) and Automated Vehicle Location (AVL) data, the method relaxes some of the limitations of existing approaches. The problem is modeled using a mixture distribution framework that incorporates a priori structural information. It is data-driven and requires neither observations of denied boardings, nor assumptions about access/egress time distributions.

Also, for comparison purposes, the paper presents an event-based deterministic transit assignment model with explicit capacity constraints. While the network assignment works at the network level and requires train capacity, the mixture model works at the station level, requires no external parameters, and can be easily applied to any station and for any time period. A case study illustrates the application of the proposed methods using actual data and compares the results against existing methods, and also survey data. The results demonstrate the mixture model's robustness and applicability for monitoring denied boarding.

228. Critical multi-link disruption identification for public transport networks: A multi-objective optimization framework

1. Iliopoulou, Christina; Makridis, Michail A.
2. PHYSICA A-STATISTICAL MECHANICS AND ITS APPLICATIONS

Public transportation networks are vulnerable to uncertainty, which manifests in various forms, disrupting their operations and leading to delays and passenger dissatisfaction. Strategic-level planning of public transport networks should include the identification of critical disruption scenarios that may result in the loss of network functionality and increased travel times for users. Existing studies on transit network vulnerability have focused on identifying isolated critical links, overlooking simultaneous failures and their impacts. In this context, this study presents a multi-objective algorithm based on Adaptive Variable Neighborhood Search (MO-AVNS) to identify critical disruption scenarios affecting transit network serviceability, using a transit assignment model to capture passenger reactions to these. A set of critical combinations is generated, reflecting transit network link failures that maximize unsatisfied demand and additional travel time, capturing both users without viable travel options and passengers whose shortest-paths are disrupted. Results on a test network are presented for scenarios featuring up to five simultaneous link failures and compared to those based on centrality-based attacks. Empirical findings demonstrate that optimization-based attacks can identify scenarios that result in significant shares of disconnected passengers and high detour costs for the remaining passengers, that would be missed under single-objective approaches or centrality metrics.& COPY; 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

229. Discrepancy Between Hyperpath and Actual Route Choices Based on Smart-Card Data in Shizuoka, Japan

1. Kaewklueklom, Rattanaorn; Kurauchi, Fumitaka; Iwamoto, Takenori
2. SMART ENERGY FOR SMART TRANSPORT, CSUM2022

Understanding passengers' route choices plays an important role in public transport planning. As an alternative to traditional web-based surveys, smart cards, an emerging technology for fare collection, can be useful to obtain massive amounts of information over a long period of time. This paper determines how smart-card data can help us understand passengers' travel strategies, by identifying factors influencing route choice behaviour within the bus system of Shizuoka, Japan. We also examine the discrepancy between hyperpath and actual route choices based on smart-card data together with the choice principles proposed by Luo et al. [17] and arrival time-based route assignment. Origin-destination (OD) pairs are analysed with the goal to determine the most appropriate model for the transit assignment problem. We found a discrepancy between hyperpath and actual route choices, which was attributed to the erroneous assumption of random arrivals of bus services; in fact, bus

operation in the Shizuoka area is timetable-based. Consequently, passengers are likely to follow the bus schedule. Route choice flexibility was displayed by regular commuters, who did not strictly adhere to a single bus route even though they usually travelled according to the same origin-destination pair. This supports the concept of hyperpath travellers. A variety of factors, such as perceived crowding and uncertainty of services (delays), might also affect choices when bus routes are overcrowded and another bus is due shortly. Our findings aim to assist transport planners towards predicting traffic demand more accurately, and therefore enhancing the provided public transport services and determining influential factors for commuters' travel strategies.

230. A frequency-based maritime container assignment model

1. Bell, Michael G. H.; Liu, Xin; Angeloudis, Panagiotis; Fonzone, Achille; Hosseinloo, Solmaz Haji
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper transfers the classic frequency-based transit assignment method of Spiess and Florian to containers demonstrating its promise as the basis for a global maritime container assignment model. In this model, containers are carried by shipping lines operating strings (or port rotations) with given service frequencies. An origin-destination matrix of full containers is assigned to these strings to minimize sailing time plus container dwell time at the origin port and any intermediate transshipment ports. This necessitated two significant model extensions. The first involves the repositioning of empty containers so that a net outflow of full containers from any port is balanced by a net inflow of empty containers, and vice versa. As with full containers, empty containers are repositioned to minimize the sum of sailing and dwell time, with a facility to discount the dwell time of empty containers in recognition of the absence of inventory. The second involves the inclusion of an upper limit to the maximum number of container moves per unit time at any port. The dual variable for this constraint provides a shadow price, or surcharge, for loading or unloading a container at a congested port. Insight into the interpretation of the dual variables is given by proposition and proof. Model behaviour is illustrated by a simple numerical example. The paper concludes by considering the next steps toward realising a container assignment model that can, amongst other things, support the assessment of supply chain vulnerability to maritime disruptions. (C) 2011 Elsevier Ltd. All rights reserved.

231. Optimal Hyperpaths With Non-Additive Link Costs

1. Maadi, Saeed; Schmocker, Jan-Dirk
2. PAPERS SELECTED FOR THE 22ND INTERNATIONAL SYMPOSIUM ON TRANSPORTATION AND TRAFFIC THEORY

Non-additive link cost functions are common and important for a range of assignment problems. In particular in transit assignment, but also a range of other problems path splits further need to consider node cost uncertainties leading to the notion of hyperpaths. We discuss the problem of finding optimal hyperpaths under non-additive link cost conditions assuming a cost vector with a limited number of marginal decreasing costs depending on the number of links already traversed. We illustrate that these non-additive costs lead to violation of Bellman's optimality principle which in turn means that standard procedures to obtain optimal destination specific hyperpath trees are not feasible. To overcome the problem we introduce the concepts of a travel history vector and active critical, passive critical and fixed nodes. The former records the expected number of traversed links until a node, and the latter distinguishes nodes for which the cost can be determined deterministically. With this we develop a 2 stage solution approach. In the first stage we test whether the optimal hyperpath can be obtained by

backward search. If this is not the case, we propose a so called selective hyperpath generation among hyperpaths to a (small) number of active critical nodes and combine this with standard hyperpath search. We illustrate our approach by applying it to the Sioux Falls network showing that even for link cost functions with large step changes we are able to obtain optimal hyperpaths in a reasonable computational time. (C) 2017 The Authors. Elsevier B.V. All rights reserved.

232. COVID-19 transmission risk minimization at public transportation stops using Differential Evolution algorithm

1. Mutlu, Mehmet Metin; Aksoy, Ilyas Cihan; Alver, Yalcin

2. EUROPEAN JOURNAL OF TRANSPORT AND INFRASTRUCTURE RESEARCH

Public transportation vehicles, with their confined spaces and limited ventilation, are considered among the primary factors in the spread of COVID-19. As a measure to slow the spread of the virus during the pandemic, governments have applied passenger capacity restrictions to ensure physical distancing. On the other hand, the increase in the risk of disease transmission associated with passengers waiting together at stops is omitted. In this study, we consider the risk of disease transmission as a travel cost and formulate a risk minimization problem as a transit network frequency setting problem. We develop a bi-level optimization model minimizing the total infection risk occurring at stops, namely, the cumulative disease transmission risk cost. The Differential Evolution algorithm is employed to cope with the NP-hard bi-level transportation network design problem. We propose a novel objective function for the upper-level model, considering the infection risk cost based on passenger traffic at public transportation stops. A congested user-equilibrium transit assignment model is utilized to determine passenger movement. The proposed model is applied to a small-size hypothetical network, and a mid-size test network. Experimental studies provide evidence that the model can produce optimal solutions. Optimization results show significant improvements in the reduction of disease transmission risk compared to the optimizations depending on the traditional practice of transportation network planning based on user and operator costs. The proposed model provides risk cost reductions of 51% and 22% compared to the optimal solutions based on user cost minimization in the hypothetical network and Mandl's network, respectively.

233. A Network-Based Model of Passenger Transfer Flow between Bus and Metro: An Application to the Public Transport System of Beijing

1. Wang, Wenjing; Wang, Yihong; Correia, Goncalo Homem de Almeida; Chen, Yusen

2. JOURNAL OF ADVANCED TRANSPORTATION

In a multimodal public transport network, transfers are inevitable. Planning and managing an efficient transfer connection is thus important and requires an understanding of the factors that influence those transfers. Existing studies on predicting passenger transfer flows have mainly used transit assignment models based on route choice, which need extensive computation and underlying behavioral assumptions. Inspired by studies that use network properties to estimate public transport (PT) demand, this paper proposes to use the network properties of a multimodal PT system to explain transfer flows. A statistical model is estimated to identify the relationship between transfer flow and the network properties in a joint bus and metro network. Apart from transfer time, the number of stops, and bus lines, the most important network property we propose in this study is transfer accessibility. Transfer accessibility is a newly defined indicator for the geographic factors contributing to the possibility of transferring at a station, given its position in a multimodal PT network, based on an adapted gravity-

based measure. It assumes that transfer accessibility at each station is proportional to the number of reachable points of interest within the network and dependent on a cost function describing the effect of distance. The R-squared of the regression model we propose is 0.69, based on the smart card data, PT network data, and Points of Interest (POIs) data from the city of Beijing, China. This suggests that the model could offer some decision support for PT planners especially when complex network assignment models are too computationally intensive to calibrate and use.

234. A new methodology for the public transport network design

1. Ciaffi, Francesco; Cipriani, Ernesto; Petrelli, Marco; Uspalyte-Vitkuniene, Rasa
2. 9TH INTERNATIONAL CONFERENCE ENVIRONMENTAL ENGINEERING (9TH ICEE) - SELECTED PAPERS

The present paper deals with the bus network design problem. Such problem is formulated as an optimization problem involving the minimization of all resources and costs related to the public transport system. The optimization problem is subject to user equilibrium on public transport network as well as to the bus capacity constraints and a set of feasibility constraints on route length and line frequency. The objective function is defined as the sum of operator's costs and users' costs. The input data are the public transport demand matrix, the characteristics of road network, the operating and users unit costs. Outputs are routes and frequencies for the lines of the public transport network. The performances of the network are estimated by a hyperpath transit assignment model, which reproduces the choice behaviour of transit users. The solving procedure consists of a set of heuristics, which includes a first routine for the definition of the roads and the zones to be served, a second step for the routes generation and then a genetic algorithm for finding a sub-optimal set of routes and associated frequencies. The GA is implemented in the C# language as a parallel genetic algorithm while the fitness evaluation requires computing, for each solution generated, the two terms of the objective function by simulating the public transport network with the EMME software. The proposed procedure will be implemented on a real large size network (two districts in the city of Rome), in order to compare its effectiveness with the performances of the existing transit network and to provide an extensive sensitivity analysis in bus frequency changes.

235. Freight Transit Assignments for an Integrated Network of Road Transportation and Underground Logistics Systems

1. Chen, Yicun; Liu, Ying; Guo, Dongjun; Chen, Zhilong; Li, Xiao
2. JOURNAL OF PIPELINE SYSTEMS ENGINEERING AND PRACTICE

Alleviating the pressure due to increasing freight transportation traffic by using low-emission and innovative transportation methods can reduce a number of problems, such as transportation network capacity limits and environmental pollution, and contribute to the development of resource-efficient and sustainable cities in the future. An underground logistics system (ULS) can improve the service quality and transportation efficiency of urban logistics and alleviate traffic congestion and associated problems, such as energy consumption and air pollution. Previous studies on urban ULS have primarily focused on technical feasibility and policy requirements, whereas analyses of the effects of introducing ULS on the existing transportation network are scarce. The main goal of the present research is to develop a method of freight transit assignment for an integrated transportation network of aboveground roads and the main line and branch lines of the ULS. A formulation for an integrated transportation problem of freight for roads and ULS was established along with a process that considers the loading, unloading, and transfer of freight among each mode. Based on the random

utility theory method, a stochastic assignment model was used to divert freight from the road to the ULS using a network that possesses critical transport features, including multiple freight demands and alternative transit routes. The influence of several factors, such as travel speed, departure frequency, and the capacity limitations of lines and nodes, was analyzed, and the results showed that the ULS was the preferred mode of freight transportation. Freight transportation via ULS is more efficient than road transportation, which provides a foundation for further investigation into the integration of ULS in road transportation networks in aboveground and underground spaces.

236. Local User Cost Equilibrium: a bush-based algorithm for traffic assignment

1. Gentile, Guido
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

This article presents a new algorithm for traffic assignment, called Local User Cost Equilibrium (LUCE), which iteratively solves a sequence of user-equilibrium problems associated with flows exiting from a node. The method is based on the idea of assigning users directed towards each destination separately; these flows form a bush, i.e. an acyclic sub-graph that connects every node to that destination. For each node, the algorithm considers the arcs of its forward star as the set of travel alternatives available to users and seeks a deterministic equilibrium of flows towards the same destination. The cost function associated with each of these local route choices expresses the average impedance to reaching the destination if a user continues the trip on a particular arc. The method is 'local' in an analytical sense, because the cost function is linearised at the current flow pattern, as if it was independent from the other splitting rates of the same node. The method is also 'local' in a topological sense, as nodes are processed through a polynomial visit of the current bush, inspired by dynamic programming. The node problem is formulated as a quadratic program in terms of destination-specific flows. We prove that its solution recursively applied in topological order provides a descent direction with respect to the sum-integral objective function of traffic assignment. The local equilibrium problem at nodes is solved through a greedy algorithm resembling the ad-hoc method used to compute shortest hyperpaths in transit assignment. The latter is the main contribution of this article. The main advantage of LUCE is to achieve a fast convergence rate that compares favourably with the existing methods, and to implicitly assign the demand flow of each origin-destination pair on several paths at once.

237. APPLICATION OF A NEW RAPID TRANSIT NETWORK DESIGN MODEL TO BUS RAPID TRANSIT NETWORK DESIGN: CASE STUDY ISFAHAN METROPOLITAN AREA

1. Kermanshahi, Shahab; Shafahi, Yousef; Bagherian, Mehdi
2. TRANSPORT

The problem of Rapid Transit Network Design (RTND) is studied in this paper. Due to the noticeable contribution of rapid transit lines in public transportation network of large urban areas, this problem is interesting to the transportation specialists. On the other hand, the success stories of Bus Rapid Transit (BRT) systems in different countries have motivated us to study BRT network planning. BRT systems can be developed with less investment costs and construction time in comparison with rail-based systems. Therefore, planning Bus Rapid Transit lines, either to develop a new rapid transit network or extend a current one can be an interesting research topic. This problem, like other network design problems is difficult to solve for large scale networks. In this study, a mixed-integer mathematical model that addresses the Transit Network Design Problem (TNDP) is presented. The objective function of the

model is maximization of trip coverage. To solve the model, an algorithm is proposed and implemented in C# environment. The main modules of the algorithm are the following: (1) routes generation, (2) search tree, (3) solution evaluation, and (4) inference. In Route Generation module, the candidate transit route set is determined. Afterwards, the Search Tree module provides a strategy which guarantees that all feasible combinations can be considered in the search process. To evaluate the performance of each transit route combination, a transit assignment algorithm is used in the Solution Evaluation part. Finally, the intelligence core of the search process, that is called Inference, helps the algorithm to find parts of the search space which cannot contain the optimal solution. The algorithm is tested on a real size network, i.e., the extension of the Greater Isfahan rapid transit network with BRT routes. The output of the algorithm is the set of BRT routes that maximizes the daily trip coverage index while satisfying the budget constraint. By solving the case study problem, it is shown that our proposed model and algorithm are capable of tackling real size rapid transit network design problems.

238. Integrating travel demand modeling and flood hazard risk analysis for evacuation and sheltering

1. Kim, Karl; Pant, Pradip; Yamashita, Eric

2. INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION

In this paper, the risks of flooding hazards to the transportation system in urban Honolulu are assessed using a regional travel demand model (TDM). The approach serves to support understanding of evacuation and sheltering needs. Coastal and inland flooding hazard scenarios were modeled with four different hazard conditions. The inundation defined by the Maximum Envelope of High Water (MEOW) based on a hurricane that struck Hawaii and a tsunami run-up generated by historical earthquake events combined with a one-meter rise in sea level provided the worst possible coastal flooding scenario. A 500-year return period riverine flooding scenario was also included. The critical flooding hazard was transformed into a uniform 100 by 100 meter GIS based grid system. The Oahu Metropolitan Planning Organization (OMPO) TransCAD model for 2035 provided the origin and destination trips for eleven trip types including motorized and non-motorized travel modes. The OMPO model includes personal travel, travel to the airport, commercial vehicle travel and visitor travel sub-models. Origin and destination trip matrices for Traffic Analysis Zones (TAZ) and highway and transit assignment details were extracted from the model. The O-D trips and road segment traffic details were transformed to the spatial grid system and overlaid on the flooding hazard layer. The spatial categorization of the flooding along with the trip and travel data from the TDM provided a robust method to quantify and visualize risks to travelers and the transportation system. The analysis shows that flooding hazard scenarios have serious risks in Honolulu. First, a large portion of the study area is susceptible to flooding, threatening the population, economy, and infrastructure. Second, in addition to areas susceptible to flooding, a larger percentage of origins, destinations, trips and vehicle miles of travel (VMT) are affected because of the need to travel through the at-risk areas. Third, commercial, transit and non-motorized trips are disproportionately affected compared to auto travel. This paper demonstrates how hazard data and risk models can be integrated with travel demand models for purposes of evacuation planning and sheltering as well as emergency planning and hazard mitigation and adaptation of the transportation system to climate change.

239. Application of constrained enumeration approach to Multimodal choice set generation

1. Hoogendoorn-Lanser, Sascha; Bovy, Piet; van Nes, Rob

2. TRANSPORTATION RESEARCH RECORD

Collected data often include only information about chosen routes. To gain insight into travelers' route choice behavior or to predict route shares, one must know the set of alternatives from which travelers have chosen their routes. An alternative approach to choice set generation in mixed multimodal networks is presented. This new algorithm—a run-based, constrained enumeration method that uses branch-and-bound techniques—is suitable for both estimation and prediction. One key characteristic of the algorithm is a set of constraints that reflects observed travel behavior. The proposed algorithm for choice set generation can be applied to a complete multimodal network at once. However, by exploiting knowledge about the structure of multimodal trips, the separate application of the algorithm to partial networks and consecutive concatenation of subroutes into complete door-to-door routes substantially reduce computation times without resulting in incomplete choice sets. This algorithm for choice set generation has been calibrated for and successfully applied to a real-size, mixed multimodal transport network in the Netherlands. A comparison of generated choice sets with reported chosen and known alternatives indicated that the algorithm can generate these alternatives, with high coverage levels as a result. This result clearly indicates that this constrained enumeration approach meets the requirements for choice set generation and thus offers interesting perspectives for route choice analysis and the prediction of route shares. Furthermore, the separate application of the algorithm to partial networks and the consecutive concatenation of subroutes into complete door-to-door trips substantially do not result in incomplete choice sets.

240. A dynamic route choice model for public transport networks with boarding queues

1. Trozzi, Valentina; Kaparias, Ioannis; Bell, Michael G. H.; Gentile, Guido

2. TRANSPORTATION PLANNING AND TECHNOLOGY

The concepts of optimal strategy and hyperpath were born within the framework of static frequency-based public transport assignment, where it is assumed that travel times and frequencies do not change over time and no overcrowding occurs. However, the formation of queues at public transport stops can prevent passengers from boarding the first vehicle approaching and can thus lead to additional delays in their trip. Assuming that passengers know from previous experience that for certain stops/lines they will have to wait for the arrival of the 2nd, 3rd, ..., k-th vehicle, they may alter their route choices, thus resulting in a different assignment of flows across the network. The aim of this paper is to investigate route choice behaviour changes as a result of the formation and dispersion of queues at stops within the framework of optimal travel strategies. A new model is developed, based on modifications of existing algorithms. (c) 2013 Taylor & Francis

241. Implementation and Application of a Stochastic Agent-based Model for Passenger Flow Distribution Predicting in Planned Metro Station Service Disruption Scenario

1. Deng, Ying; Liu, Wei; Zhang, Qi; Zhang, Zhiqing

2. 2022 IEEE 25TH INTERNATIONAL CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS (ITSC)

This paper discusses a method for predicting and evaluating the effects of planned station service disruptions. A three-layer model is used to describe the travel behavior of passengers in terms of the origin and destination station selection process, the path planning process, and the train selection process, and the model is built for both normal situation and station closure situations respectively. On this basis, the calibrated agent-based simulation models under normal and station closure situations

are established for simulating and counting the distribution and status of passengers and trains on the metro network, which can effectively predict the passenger flow distribution during a planned station service disruption. Shanghai Metro is taken as a case study, and the simulation results were validated against the historical data demonstrating that the proposed model is able to predict the changes in both number and trend of passenger volume. One platform of People's Square Station has a maximum of over 1000 passengers at a time and needs special attention on waiting zone organization. This study offers a new and cost-effective approach to risk management of metro network for operators.

242. SmartTransfer: Modeling the Spatiotemporal Dynamics of Passenger Transfers for Crowdedness-Aware Route Recommendations

1. Du, Bowen; Cui, Yifeng; Fu, Yanjie; Zhong, Runxing; Xiong, Hui
2. ACM TRANSACTIONS ON INTELLIGENT SYSTEMS AND TECHNOLOGY

In urban transportation systems, transfer stations refer to hubs connecting a variety of bus and subway lines and, thus, are the most important nodes in transportation networks. The pervasive availability of large-scale travel traces of passengers, collected from automated fare collection (AFC) systems, has provided unprecedented opportunities for understanding citywide transfer patterns, which can benefit smart transportation, such as smart route recommendation to avoid crowded lines, and dynamic bus scheduling to enhance transportation efficiency. To this end, in this article, we provide a systematic study of the measurement, patterns, and modeling of spatiotemporal dynamics of passenger transfers. Along this line, we develop a data-driven analytical system for modeling the transfer volumes of each transfer station. More specifically, we first identify and quantify the discriminative patterns of spatiotemporal dynamics of passenger transfers by utilizing heterogeneous sources of transfer related data for each station. Also, we develop a multi-task spatiotemporal learning model for predicting the transfer volumes of a specific station at a specific time period. Moreover, we further leverage the predictive model of passenger transfers to provide crowdedness-aware route recommendations. Finally, we conduct the extensive evaluations with a variety of real-world data. Experimental results demonstrate the effectiveness of our proposed modeling method and its applications for smart transportation.

243. An assignment model for public transport networks with both schedule- and frequency-based services

1. Eltvéd, Morten; Nielsen, Otto Anker; Rasmussen, Thomas Kjaer
2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

This paper presents an assignment modeling framework for public transport networks with co-existing schedule- and frequency-based services. The paper develops, applies and discusses a joint model, which aims at representing the behavior of passengers as realistically as possible. The model consists of a choice set generation phase followed by a multinomial logit route choice model and assignment of flow to the generated alternatives. The choice set generation uses an event dominance principle to exclude alternatives with costs above a certain cost threshold. Furthermore, a heuristic for aggregating overlapping lines is proposed. The results from applying the model to a case study in the Greater Copenhagen Area show that the level of service obtained in the unified network model of mixed services is placed between the level of service for strictly schedule-based and strictly frequency-based networks. The results also show that providing timetable information to the passengers improve their utility function as compared to only providing information on frequencies.

244. THE HIGH-OCCUPANCY VEHICLE LANE DESIGN PROBLEM IN A MULTI-MODAL TRANSPORT NETWORK

1. Wu, Z. X.; Lam, William H. K.
2. TRANSPORTATION AND LOGISTICS

The construction of high-occupancy vehicle (HOV) lanes has been regarded as an efficient method to reduce road traffic congestion and to provide car users with additional modal choice. This paper addresses the HOV lane design problem in a general multi-modal transport network. Specifically, given a network of candidate HOV lanes, each existing (general purpose) lane can be converted to a HOV lane or not; also, each established HOV lane can be open to bus only or to both bus and carpooling. In this paper, a bi-level programming model is developed for this HOV design problem. The upper level seeks to minimize the total cost of the multi-modal transport system while the lower level is the multi-modal stochastic traffic assignment model in which the carpooling option is incorporated and the interactions among different modal flows sharing the same road space are captured. A numerical example is used to illustrate that the proposed model can be solved by two heuristic algorithms.

245. A SCHEDULE-BASED APPROACH IN DYNAMIC ASSIGNMENT MODELLING FOR PUBLIC TRANSPORT NETWORKS

1. Nuzzolo, Agostino; Russoz, Francesco; Crisalli, Umberto
2. TRANSPORTATION PLANNING AND MANAGEMENT IN THE 21ST CENTURY

This paper describes a class of schedule-based dynamic assignment models for transit networks. These models allow us to define more coherent user behavioural hypotheses in path choice models, which are the core of assignment models, in relation to service and user characteristics. The dynamic evolution of the transit system, considering both a single day period (within-day dynamic) and a sequence of day periods (day-to-day dynamic) for different types of transit systems (high and low frequency services) is investigated, as well as some theoretical properties of dynamic assignment models for transit networks are reported.

246. Capacity constrained accessibility of high-speed rail

1. Shen, Yu; Zhao, Jinhua
2. TRANSPORTATION

This paper proposes an enhanced measure of accessibility that explicitly considers circumstances in which the capacity of the transport infrastructure is limited. Under these circumstances, passengers may suffer longer waiting times, resulting in the delay or cancellation of trips. Without considering capacity constraints, the standard measure overestimates the accessibility contribution of transport infrastructure. We estimate the expected waiting time and the probability of forgoing trips based on the M/G(B)/1 type of queuing and discrete-event simulation, and formally incorporate the impacts of capacity constraints into a new measure: capacity constrained accessibility (CCA). To illustrate the differences between CCA and standard measures of accessibility, this paper estimates the accessibility change in the Beijing-Tianjin corridor due to the Beijing-Tianjin intercity high-speed railway (BTIHSR). We simulate and compare the CCA and standard measures in five queuing scenarios with varying demand patterns and service headway assumptions. The results show that (1) under low system loads condition, CCA is compatible with and absorbs the standard measure as a special case; (2) when demand increases and approaches capacity, CCA declines significantly; in two quasi-real scenarios, the

standard measure overestimates the accessibility improvement by 14-30 % relative to the CCA; and (3) under the scenario with very high demand and an unreliable timetable, the CCA is almost reduced to the pre-BTIHSR level. Because the new CCA measure effectively incorporates the impact of capacity constraints, it is responsive to different arrival rules, service distributions, and system loads, and therefore provides a more realistic representation of accessibility change than the standard measure.

247. Study an optimal frequency design problem for multimodal network using probit-based user equilibrium assignment

1. Uchida, K; Sumalee, A; Watling, D; Connors, R
2. NETWORK MODELING 2005

In this paper, a probit-based multimodal transport assignment model is developed. Three transport modes (railway system, bus system, and automobiles) and their interactions are considered. The walking time to a bus stop or a station also plays an important role in multimodal networks. Thus, walking to a bus stop or to a railway station is included in the model. The factors affecting travelers' route choices considered in this model include actual travel times, discomfort effects on transit systems, expected waiting times, fares, and constants specific to transport modes. A route in the model may be composed of different modes. The paper also deals with the optimal transit frequency design problem. The frequency design problem is formulated as an implicit program in which the objective function of total disutility in the multimodal network is minimized with respect to frequencies of transit lines. The flows on a multimodal network follow a probit-based stochastic user equilibrium assignment. A numerical example is presented.

248. Exploring the robustness of public transportation system on augmented network: A case from Nanjing China

1. Jin, Kun; Wang, Wei; Li, Xinran; Hua, Xuedong; Qin, Shaoyang
2. PHYSICA A-STATISTICAL MECHANICS AND ITS APPLICATIONS

A highly robust urban public transportation network is the foundation for the stable and sustainable development of a city. Managers may benefit from a reasonable investigation into the robustness of the public transportation system to recognize and deliver improved public transportation services. This paper developed a robustness analysis framework for public transportation systems on augmented network (AN). Specifically, an AN was first built to treat the public transit network from a multi-layer perspective. The AN carefully considers the boarding, alighting, riding and transfer behaviors, and develops cost functions under the congestion effect, thus sufficiently simulating the real passengers' behaviors. Then, the user equilibrium (UE) assignment model, a model widely used for passenger flow forecasting, is applied to guide the robustness analysis under cascading failures. Finally, a real large-scale bus-rail hybrid network in Nanjing is used as a case study. The results show that the initial station capacities are significant to the impact of the cascading failure, from which we conclude that a larger initial capacity of stations can prevent the cascading failures. By investigating the relationship between passenger flow and cascade size, the comparative results further explain the mechanisms of cascading failures. Thanks to the AN and UE, three types of travel times can be compared to reflect the quality of public passenger trips, which should provide traffic managers with pertinent advice for improving service.(c) 2022 Elsevier B.V. All rights reserved.

249. Using Smart Card Data Trimmed by Train Schedule to Analyze Metro Passenger Route Choice with Synchronous Clustering

1. Li, Wei; Luo, Qin; Cai, Qing; Zhang, Xiongfei
2. JOURNAL OF ADVANCED TRANSPORTATION

The metro passenger route choice, influenced by both train schedule and time constraints, is important to metro operation and management. Smart card data (Automatic Fare Collection (AFC) data in metro system) including inbound and outbound swiping time are useful for analysis of the characteristics of passengers' route choices in metro while they could not reflect the property of train schedule directly. Train schedule is used in this paper to trim smart card data through removing inbound and outbound walking time to/from platforms and waiting time. Thus, passengers' pure travel time in accord with trains' arrival and departure can be obtained. Synchronous clustering (SynC) algorithm is then applied to analyze these processed data to calculate passenger route choice probability. Finally, a case study was conducted to illustrate the effectiveness of the proposed algorithm. Results showed the proposed algorithm works well to analyze metro passenger route choice. It was shown that passenger route choice during both peak period and flat period could be clustered automatically, and noise data are isolated. The probability of route choice calculated through SynC algorithm can be used to revise traditional model results.

250. The schedule-based dynamic modelling for public transport networks: a new approach in path choice and assignment

1. Nuzzolo, A; Russo, F; Crisalli, U
2. URBAN TRANSPORT VIII: URBAN TRANSPORT AND THE ENVIRONMENT IN THE 21ST CENTURY

This paper presents a general overview of the schedule-based approach in dynamic path choice and assignment models for transit networks. The first part describes different specification of path choice models in relation to different user and service characteristics. The latter deals with a classification of assignment models.

251. Modeling the effect of real-time crowding information (RTCI) on passenger distribution in trains

1. Peftitsi, Soumela; Jenelius, Erik; Cats, Oded
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

Overcrowding has become a big challenge for public transport systems, affecting passengers' travel experience. At the same time, service supply is often underutilized due to large variations in crowding across services, vehicle trips on the same service and different compartments of the same vehicle. Real-time operational measures, such as information provision, can potentially reduce on-board crowding unevenness and its negative effects. In this study, we extend a dynamic public transport simulation model to provide passengers with predictive real-time crowding information (RTCI) concerning individual train cars. Passengers utilize this information when choosing a specific train car to board. It is demonstrated through a case study for the Stockholm metro network area that in the presence of car-specific crowding information, passengers alter their car boarding choices to avoid on-board crowding, leading to a more even passenger distribution inside trains. We find that passengers' travel experience improves with the provisioning of RTCI, which is a result of the lower on-board crowding unevenness.

Moreover, this improvement increases with increased demand levels but only up to a certain point beyond which passengers do not gain from switching train cars.

252. Balancing the GHG emissions and operational costs for a mixed fleet of electric buses and diesel buses

1. Shao, Shuai; Tan, Zhijia; Liu, Zhiyuan; Shang, Wenlong
2. APPLIED ENERGY

Making the urban buses electric is regarded as a major strategy to reduce greenhouse gas (GHG) emissions and environmental impacts of fossil fuels. In practice, not all diesel buses (DBs) are replaced by electric buses (EBs) because of budget constraint. This paper investigates the balance of the deployment problem for a mixed fleet with DBs and EBs in the sense of total GHG emissions and operational costs by incorporating the effect of the spatial-temporal passenger flows. The balance strategy of fleet deployment is defined the Pareto optimal allocation of EBs among bus lines to minimize simultaneously the total operational cost and GHG emissions. A real-world urban bus system of Liuzhou City in China is conducted. We find that the bus lines located in the downtown with higher passenger loading would prefer to adopt EBs at the peak hours, and most DBs are allocated to the bus lines with long travel distance at off-peak hours in the suburb. Therefore, the reduced emission by adopting EBs mainly concentrates on the center of the city, and more produced emissions of DBs are distributed far away from the downtown. When all DBs replaced by EBs, the upper bound of the carbon emission reduction ratio is 77.04%, which reduces from 207.15 tons to 47.56 tons per day.

253. Schedule-Based Passenger Assignment for High-Speed Rail Networks considering the Ticket-Booking Process

1. Su, Huanyin; Shi, Feng; Xu, Guangming; Qin, Jin; Shan, Xinghua
2. MATHEMATICAL PROBLEMS IN ENGINEERING

This paper proposes a schedule-based passenger assignment method for high-speed rail networks considering the ticket-booking process. Passengers book tickets to reserve seats during the presale period in high-speed rail systems and passengers on trains are determined during the ticket-booking process. The ticket-booking process is modeled as a continuous and deterministic predecision process. A solution algorithm is designed using the discretization of the continuous process by partitioning the ticket-booking time and the optimal paths remain constant in any partition interval. Finally, an application to the Chinese high-speed rail network is presented. A comparison of the numerical results with the reality is conducted to validate the efficiency and precision of the method and algorithm. Based on the results, the operating efficiency of the current train schedule is evaluated and some specific improvement measures are proposed.

254. The impact of using a naive approach in the limited-stop bus service design problem

1. Suman, Hemant; Larrain, Homero; Carlos Munoz, Juan
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

The proven benefits of limited-stop services have captured the attention of researchers, especially during the last decade. However, to solve the limited-stop service design problem many existing works directly impose a capacity constraint to a total social cost objective function. This naive approach implicitly assumes that passengers behave altruistically, basing their decisions on what is best for the

whole system. Although this issue has been identified in earlier works, the magnitude of the error induced by this simplification has not been studied yet. The objective of this work is to measure this error and to understand how it misrepresents passenger flows and bus occupation rates. To measure this error gap, we optimize a set of test scenarios by applying a naive approach, and then take the resulting design and obtain a benchmark passenger assignment using a simple behavioral model. We propose two main indicators to compare both passenger assignment: the total passenger deviation, and the total capacity deficit. This comparison reveals that the assignment of the naive approach may indeed be unrealistic, and raises concerns that a network design based on the naive approach might have severe problems when implemented. Thus, the work highlights the importance of taking the results of the naive approach with caution and verify them with a passenger assignment model before their implementation.

255. The line planning routing game

1. Schiewe, Alexander; Schiewe, Philine; Schmidt, Marie
2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

In this paper, we take a novel perspective on line planning in public transportation: We interpret line planning as a game where the passengers are players who aim at minimizing individual objective functions composed of travel time, transfer penalties, and a share of the overall cost of the solution. We discuss the relation among equilibria of this game and line planning solutions found by optimization approaches. Furthermore, we investigate the algorithmic viability of our approach as a solution method for line planning problems, using a best-response algorithm to find equilibria. We investigate under which conditions a passenger's best-response can be calculated efficiently and which properties are needed to guarantee convergence of the best-response algorithm. (C) 2018 Elsevier B.V. All rights reserved.

256. Precise estimation of connections of metro passengers from Smart Card data

1. Hong, Sung-Pil; Min, Yun-Hong; Park, Myoung-Ju; Kim, Kyung Min; Oh, Suk Mun
2. TRANSPORTATION

The aim of this study is to estimate both the physical and schedule-based connections of metro passengers from their entry and exit times at the gates and the stations, a data set available from Smart Card transactions in a majority of train networks. By examining the Smart Card data, we will observe a set of transit behaviors of metro passengers, which is manifested by the time intervals that identifies the boarding, transferring, or alighting train at a station. The authenticity of the time intervals is ensured by separating a set of passengers whose trip has a unique connection that is predominantly better by all respects than any alternative connection. Since the connections of such passengers, known as reference passengers, can be readily determined and hence their gate times and stations can be used to derive reliable time intervals. To detect an unknown path of a passenger, the proposed method checks, for each alternative connection, if it admits a sequence of boarding, middle train(s), and alighting trains, whose time intervals are all consistent with the gate times and stations of the passenger, a necessary condition of a true connection. Tested on weekly 32 million trips, the proposed method detected unique connections satisfying the necessary condition, which are, therefore, most likely true physical and schedule-based connections in 92.6 and 83.4 %, respectively, of the cases.

257. Dynamic Passenger Assignment during Disruptions in Railway Systems

1. Zhu, Yongqiu; Goverde, Rob M. P.

2. 2017 5TH IEEE INTERNATIONAL CONFERENCE ON MODELS AND TECHNOLOGIES FOR INTELLIGENT TRANSPORTATION SYSTEMS (MT-ITS)

Passenger-oriented rescheduling problems receive increasing attention. However, the passenger assignment models used for evaluating the rescheduling solutions are usually simplified by many assumptions. To estimate passenger inconvenience more accurately, this paper establishes a dynamic passenger assignment model during disruptions, in which the time-dependent demand, disruption-induced service variations and vehicle capacities are all taken into account. Event-based simulation is adopted to implement the model of the dynamic loading and unloading procedures of passengers. Based on the model, individual travels can be tracked, thus making the estimation of individual passenger delay possible. By aggregating individual inconvenience, the performance of a given rescheduling solution/contingency plan can be evaluated. Furthermore, recommendations such as adding train units can also be proposed, as illustrated in the case study.

258. Counting the different efficient paths for transportation networks and its applications

1. Meng, Q; Lee, DH; Cheu, RL

2. JOURNAL OF ADVANCED TRANSPORTATION

This paper deals with an interesting problem about how to efficiently compute the number of different efficient paths between an origin-destination pair for a transportation network because these efficient paths are the possible paths used by drivers to some extent. Based on a novel triangle operation derived, it first presents a polynomial-time combinatorial algorithm that can obtain the number of different simple paths between any two nodes for an acyclic network as well as the total travel cost of these paths. This paper proceeds to develop a combinatorial algorithm with polynomial-time complexity for both counting the different efficient paths between an origin-destination pair and calculating the total travel cost of these paths. As for applications, this paper shows that the preceding two algorithms can yield the lower and upper bounds for the number of different simple paths between an origin-destination pair, while it has already been recognized that a polynomial-time algorithm getting such a number does not exist for a general network. Furthermore, the latter algorithm can be applied for developing a heuristic method for the traffic counting location problem arising from the origin-destination matrix estimation problems.

259. Calculating conditional passenger travel time distributions in mixed schedule- and frequency-based public transport networks using Markov chains

1. Gardner, Clara Brimnes; Nielsen, Sara Dorthea; Eltvéd, Morten; Rasmussen, Thomas Kjaer; Nielsen, Otto Anker; Nielsen, Bo Friis

2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Calculation of passenger travel time distributions in public transport networks is important for the evaluation of the level of service provided to passengers. Passenger travel times are deterministic for punctual and uncongested networks, but in reality usually have random fluctuations caused by vehicle delays and other incidents. Advanced methods are therefore needed to calculate the passenger travel time distribution between a given origin and destination. This paper presents a novel approach for calculating the travel time distribution from origin to destination based on vehicle delays and possible missed connections in a mixed schedule and frequency-based public transport network. Markov chains

are used to model the network, making the travel time from the origin to the destination phase-type distributed. The approach is flexible with regard to the specification of vehicle travel times and provides the distribution of passenger travel times without any need for simulation. Additionally, it facilitates detailed analyses of passenger travel times conditional on the usage of specific line segments or stops. The merits of this approach are demonstrated using a case study from Copenhagen.

260. Evaluating Bus Dwell Time at Key Stops Using Automatic Data Collection Systems

1. Moosavi, Seyed Mohammad Hossein; Ismail, Amiruddin; Balali, Ardalan
2. ITE JOURNAL-INSTITUTE OF TRANSPORTATION ENGINEERS

In this study, bus dwell time is defined as the duration consumed by passengers alighting and boarding at a key stop. Some other activities may be involved in this duration of time such as lift operation. 1 Bus dwell time is of great importance in estimating the capacity of a bus station, and it is also a major component of bus travel time.(2,3,4) Also, functions of dwell time play an important role in service planning and reliability analysis of the transit route.(5,6,7,8,9) Therefore, it is a must for bus service providers and transport planners to evaluate bus dwell time in detail.(10)

261. A Two-Layer Optimization Model for High-Speed Railway Line Planning

1. Wang, Li; Jia, Li-min; Qin, Yong; Xu, Jie; Mo, Wen-ting
2. CHINA'S HIGH-SPEED RAIL TECHNOLOGY: AN INTERNATIONAL PERSPECTIVE

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262. Real-time seat allocation for minimizing boarding/alighting time and improving quality of service and safety for passengers

1. Yazdani, Danial; Omidvar, Mohammad Nabi; Deplano, Igor; Lersteau, Charly; Makki, Ahmed; Wang, Jin; Trung Thanh Nguyen
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

Rail is considered as one of the most important ways of transferring passengers. High passenger loads has implications on train punctuality. One of the important parameters affecting punctuality is the average boarding/alighting time. Organizing boarding/alighting flows not only reduces the risk of extended dwell time, but also minimizes the risk of injuries and improves the overall service quality. In this paper, we investigate the possibility of minimizing the boarding/ alighting time by maintaining a uniform load on carriages through systematic distribution of passengers with flexible tickets, such as season or anytime tickets where no seat information are provided at the time of reservation. To achieve this, the proposed algorithm takes other information such as passenger final destination, uniform load of luggage areas, as well as group travelers into account. Moreover, a discrete event simulation is designed for measuring the performance of the proposed method. The performance of the proposed method is compared with three algorithms on different test scenarios. The results show the superiority of the proposed method in terms of minimizing boarding/alighting time as well as increasing the success rate of assigning group of seats to group of passengers.

263. The impact of irregular headways on seat availability

1. Babaei, Mohsen; Schmoecker, Jan-Dirk; Shariat-Mohaymany, Afshin

2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

This paper introduces seat availability reliability, a new reliability measure that assesses the performance of transit lines. This alternative reliability indicator is defined in terms of the coefficient of variation, which examines the relative deviation of seat availability. An analytical approach is utilized based on the conditional expectation to achieve relationships for the mean and variance of the number of boarding and alighting passengers and seat availability at stops. Furthermore, confidence intervals for seat availability are derived. It is proposed that such information might be useful for traveler information systems. The proposed model is applied to a schematic transit line to show how sensitive seat availability is to headway variation (irregular dispatching) and demand uncertainty.

264. Last-Mile Shuttle Planning for Improving Bus Commuters' Travel Time Reliability: A Case Study of Beijing

1. Kou, Weibin; Wang, Jiayu; Liu, Yanxi; Li, Chenxu

2. JOURNAL OF ADVANCED TRANSPORTATION

This study proposes a multiobjective mixed integer nonlinear programming model for a last-mile shuttle service to improve bus commuters' travel time reliability. The approach aims to assign the routes that pick up the transit passengers located at the different stops by shuttle service. A bilevel optimization model is established: the upper model of route design considers the tradeoff between time cost and fare cost when some of the passengers take the shuttles, and the lower model assigns the demand of transit passengers. The proposed model effectively captures the reliability of travel time because related parameters are estimated by a statistical fitting test with a large number of real-world bus geographic information system (GPS) data. Moreover, dynamic demand diverting from conventional transit to shuttle service and travel time reliability, including passenger in-vehicle time (IVT) and waiting time (WT), are fully considered in this model. Since the task is a nonlinear programming model, a two-stage algorithm combined with linearization processing is presented to find an optimal solution. Finally, from the case study of Zhongguancun Software Park zone in Beijing, it is indicated that when last-mile shuttle service is provided, bus passengers' travel time reliability of last-mile trips can be improved by 14%. The study can be an important reference for improving the low reliability widely existing in the current transit commuters' last-mile problem.

265. Integration between activity-based demand models and multimodal assignment: Some empirical evidences

1. Cipriani, E.; Crisalli, U.; Gemma, A.; Mannini, L.

2. CASE STUDIES ON TRANSPORT POLICY

Aiming at supporting decision makers in transport policy choices, transport models used for decades the trip-based approach for travel demand forecasts. This approach, despite suited to peak hours modelling where systematic trips are predominant, suffers the limits of not being related to the sequence of activities usually undertaken in real day-life. Differently, in the Activity Based Models (ABM) the travel demand is explicitly modelled as the result of individuals' involvement in different activities in different times and locations. The use of such models is recommended when complex trip chains connected to the multiple daily activities that characterise today's life have to be taken into account, even if the integration with other sub-models (particularly with the assignment) within the

whole transport modelling procedure has to be carefully considered. For this reason, this paper focuses on the integration between ABM and transport assignment by investigating the multimodal demand-supply interaction. Specifically, the consistency between ABM and assignment models is studied proposing a methodology that can be applied to large real size networks. It is based on a multimodal static equilibrium assignment, which is easy-to-use and less time consuming with respect to a Dynamic Traffic Assignment (DTA), allowing a better estimation of the modal splits between alternative transport modes. Such a model also considers (road) congestion and (transit) crowding phenomena, as well as the multimodal network performances are estimated by taking into account the interaction between different modes sharing the same network facilities. The goodness of the proposed approach is investigated through the convergence analysis of both the entire integration procedure and its individual components (ABM and assignment) for a better transport simulation in urban areas. The application to an urban multimodal network of real-size dimensions (Rome) is presented to show the promising results of this research.

266. Effects from usage of pre-trip information and passenger scheduling strategies on waiting times in public transport: an empirical survey based on a dedicated smartphone application

1. Berggren, Ulrik; Brundell-Freij, Karin; Svensson, Helena; Wretstrand, Anders
2. PUBLIC TRANSPORT

Waiting times are important indicators of the degree of travel time optimisation and other behavioural traits among public transport (PT) passengers. As previous studies have shown, the level and usage of pre-trip information regarding schedule or real-time departures are important factors that influence the potential to realise travel time savings by enabling PT passengers to optimise waiting times. Most empirical evidence regarding the revealed PT travel behaviour concerning information levels is based on manual interviews or traditional travel surveys, in which there is a risk that the actual context of where and when the choice of departure time was made is not taken into account. This paper reports the results of a travel survey based on a dedicated smartphone application applied in a field study in a Swedish mid-size urban and regional context. Context-aware notification prompting was used to allow respondents to state their use of pre-trip information as well as whether they had pre-planned their trip and how contingent planning aids were used for time optimisation. The implications on passenger waiting times of the use of information regarding departure times by passengers were emphasised during analyses of the resulting data, along with personal characteristics, in which auxiliary sources such as timetable data and Automatic Vehicle Location were utilised to determine ground truth trip trajectories and trip-contextual factors. The results indicate the significance of having access to pre-trip information, especially for long trips above one hour's duration, in order to pre-plan and thereby optimise waiting times. In addition, the use and source of pre-trip information differ among age and gender groups. Trip purpose and time of day to some extent determine waiting times and choice of trip optimisation strategy (arrival or departure time).

267. Optimal Differential Pricing for Intercity High-Speed Railway Services with Time-Dependent Demand and Passenger Choice Behaviors under Capacity Constraints

1. Su, Huanyin; Peng, Shuting; Deng, Lianbo; Xu, Weixiang; Zeng, Qiongfang
2. MATHEMATICAL PROBLEMS IN ENGINEERING

Differential pricing of trains with different departure times caters to the taste heterogeneity of the time-dependent (departure time) demand and then improves the ticket revenue of railway enterprises. This paper studies optimal differential pricing for intercity high-speed railway services. The distribution features of the passenger demand regarding departure times are analyzed, and the time-dependent demand is formulated; a passenger assignment method considering departure periods and capacity constraints is constructed to evaluate the prices by simulating the ticket-booking process. Based on these, an optimization model is constructed with the aim of maximizing the ticket revenue and the decision variables for pricing train legs. A modified direct search simulated annealing algorithm is designed to solve the optimization model, and three random generation methods of new solutions are developed to search the solution space efficiently. Experimental analysis containing dozens of trains is performed on Wuhan-Shenzhen high-speed railway in China, and price solutions with different elastic demand coefficients (ϕ) are compared. The following results are found: (i) the optimization algorithm converges stably and efficiently and (ii) differentiation is shown in the price solutions, and the optimized ticket revenue is influenced greatly by ϕ , increasing by 7%-21%.

268. A two-layer optimization model for high-speed railway line planning

1. Wang, Li; Jia, Li-min; Qin, Yong; Xu, Jie; Mo, Wen-ting
2. JOURNAL OF ZHEJIANG UNIVERSITY-SCIENCE A

Line planning is the first important strategic element in the railway operation planning process, which will directly affect the successive planning to determine the efficiency of the whole railway system. A two-layer optimization model is proposed within a simulation framework to deal with the high-speed railway (HSR) line planning problem. In the model, the top layer aims at achieving an optimal stop-schedule set with the service frequencies, and is formulated as a nonlinear program, solved by genetic algorithm. The objective of top layer is to minimize the total operation cost and unserved passenger volume. Given a specific stop-schedule, the bottom layer focuses on weighted passenger flow assignment, formulated as a mixed integer program with the objective of maximizing the served passenger volume and minimizing the total travel time for all passengers. The case study on Taiwan HSR shows that the proposed two-layer model is better than the existing techniques. In addition, this model is also illustrated with the Beijing-Shanghai HSR in China. The result shows that the two-layer optimization model can reduce computation complexity and that an optimal set of stop-schedules can always be generated with less calculation time.

269. The future of the modal split in China's greenest city: Assessing options for integrating Dalian's fragmented public transport system

1. Mu, Rui; de Jong, Martin; Yu, Bin; Yang, Zhongzhen
2. POLICY AND SOCIETY

Dalian used to have a very favorable modal split (for public transport) and had the honor of being an environmentally friendly city among its peers in China only a few years ago. However, momentous and when it comes to sustainability rather deleterious is evolving in the past five years or so: automobiles have flooded the city along with car-friendly policies being promulgated at both the central and local levels of government. Consequently, the market share of public transport has been substantially eroded since then. Apart from the rapid motorization that weakened Dalian's position as a green city, another factor fueling the downward trend of transit attractiveness has been the growing fragmentation in transit services. Given the fact that the motorization process is irreversible and

restricting car purchase and use is unlikely to work out in China, if something needs to be done to maintain Dalian as a clean and comfortable living habitat, then lifting the fragmentation in the transit system is the only way to do this. Therefore, this paper explores where the fragmentation originates, and how it can be counteracted. A mathematical model is thus built to test the effectiveness of reducing fragmentation in improving transit service. And the results show that the modal split after system integration is going to tilt more strongly towards transit, while for service quality levels for users cannot expect much improvement. These modeling results have significant implications for the future public transport administration in Dalian. (C) 2012 Policy and Society Associates (APSS). Elsevier Ltd. All rights reserved.

270. Design of heterogeneous flexible-route public transportation networks under low demand

1. Petit, Antoine; Ouyang, Yanfeng

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper presents design methods for a flexible-route transit system, in which vehicles travel within predetermined areas to provide door-to-door service. The main advantage of this system is that passengers no longer have to access transit stations in order to gain service. This system is suitable for low and heterogeneous passenger demand distribution as it features a hybrid system layout that includes both a hub-and-spoke network in the peripheral region and a grid network in the central region, along with heterogeneous local routes that address local demand variations. Continuum approximation (C.A.) is used to reduce the computation burden by formulating the design problem with respect to a few decision variables. We compare the performance of the proposed transit system with (i) the typical fixed-route system, (ii) the homogeneous flexible-route grid system, and (iii) the flexible-route grid system with local routes, in hypothetical settings. It is found through our numerical examples that the integration of the three proposed features (i.e. flexible transit, local tubes, and hybrid structure), as compared to counterparts with only two or fewer features, yields lower combined agency and user costs under the assumed low heterogeneous demand distribution. We then apply the design framework to a more realistic case for the City of Changzhi, China. An implementable design for Changzhi is developed, and its performance verified with simulations, demonstrating accuracy and applicability of the proposed continuum approximation model.

271. Dynamic trucking equilibrium through a freight exchange

1. Miller, John; Nie, Yu (Marco)

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper proposes a new hyperpath-based dynamic trucking equilibrium (DTE) assignment model. Unlike existing freight assignment models, we focus on the interactions between individual truck operators that solely compete for loads advertised on an online freight exchange. The competitors are assumed to follow optimal bidding and routing strategies - represented using a hyperpath - to maximize their expected profit. The proposed DTE model (1) predicts system-wide truck flows (including empty truck flows), (2) identifies efficiency improvements gained by network-wide visibility, and (3) lays the foundation for building a system optimal model. We rewrite the DTE conditions as a variational inequality problem (VIP) and discuss the analytical properties of the formulation, including solution existence. A heuristic solution algorithm is developed to solve the VIP, which consists of three modules: a dynamic network loading procedure for mapping hyperpath flows onto the freight network,

a column generation scheme for creating hyperpaths as needed, and a method of successive average for equilibrating profits on existing hyperpaths. The model and the solution algorithm are validated by numerical experiments constructed from empirical data collected in China. The results show that the DTE solutions outperform with wide margin the benchmark solutions that either ignore inter-truck interactions or operate trucks according to suboptimal routing and bidding decisions.

272. Optimal design of promotion based demand management strategies in urban rail systems

1. Ma, Zhenliang; Koutsopoulos, Hans N.
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

Travel demand management (TDM) is used for managing congestion in urban areas. While TDM is well studied for car traffic, its application in transit is still emerging. Well-structured transit TDM approaches can help agencies better manage the available system capacity when the opportunity and investment to expand are limited. However, transit systems are complex and the design of a TDM scheme, deciding when, where, and how much discount or surcharge is implemented, is not trivial. The paper proposes a general framework for the optimal design of promotion based TDM strategies in urban rail systems. The framework consists of two major components: network performance and optimization. The network performance model updates the origin-destination (OD) demand based on the response to the promotion strategy, assigns it to the network, and estimates performance metrics. The optimization model allocates resources to maximize promotion performance in a cost effective way by better targeting users whose behavioral response to the promotion improves system performance. The optimal design of promotion strategies is facilitated by the availability of smart card (automated fare collection, AFC) data. The proposed approach is demonstrated with data from a busy urban rail system. The results illustrate the value of the method, compare the effectiveness of different strategies, and highlight the limits of the effectiveness of such strategies.

273. Modeling the impacts of public transport reliability and travel information on passengers' waiting-time uncertainty

1. Cats, Oded; Gkioulou, Zafeira
2. EURO JOURNAL ON TRANSPORTATION AND LOGISTICS

Public transport systems are subject to uncertainties related to traffic dynamic, operations, and passenger demand. Passenger waiting time is thus a random variable subject to day-to-day variations and the interaction between vehicle and passenger stochastic arrival processes. While the provision of real-time information could potentially reduce travel uncertainty, its impacts depend on the underlying service reliability, the performance of the prognosis scheme, and its perceived credibility. This paper presents a modeling framework for analyzing passengers' learning process and adaptation with respect to waiting-time uncertainty and travel information. The model consists of a within-day network loading procedure and a day-to-day learning process, which are implemented in an agent-based simulation model. Each loop of within-day dynamics assigns travelers to paths by simulating the progress of individual travelers and vehicles as well as the generation and dissemination of travel information. The day-to-day learning model updates the accumulated memory of each traveler and updates consequently the credibility attributed to each information source based on the experienced waiting time. A case study in Stockholm demonstrates model capabilities and emphasizes the importance of behavioral adaptation when evaluating alternative measures which aim to improve service reliability.

274. Station choice for Australian commuter rail lines: Equilibrium and optimal fare design

1. Wang, Shuaian; Qu, Xiaobo
2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

We examine how park-and-ride commuters living along a rail line compete for seats when they travel to their workplace in Australian metropolitan areas. First, we prove that at user equilibrium in which each commuter minimizes her expected travel cost, there exists one station on the rail line at which some commuters could find a seat and the others have to stand; all of the commuters boarding at its upstream stations have seats and all of the commuters boarding at its downstream stations must stand in the train. We derive a solution algorithm for obtaining a user equilibrium, which involves solving an equation with only one variable. We demonstrate that more than one user equilibrium may exist. Second, we examine the system optimal station choice that assumes all of the commuters cooperate and minimizes their total travel cost. An analytical solution approach is proposed based on the structure of the problem. Third, we investigate the optimal train fare design that leads to the system optimal station choice. We prove that the optimal train fare satisfies: there exists a particular train station that has some seats and the train is full after this station. All of its upstream stations have the same fare, which is higher than or equal to the fare of this particular station; and all of its downstream stations have the same fare, which is lower than the fare of this particular station. (C) 2016 Elsevier B.V. All rights reserved.

275. Modeling the Effects of Public Bicycle Schemes in a Congested Multi-Modal Road Network

1. Li, Zhi-Chun; Yao, Ming-Zhu; Lam, William H. K.; Sumalee, Agachai; Choi, Keechoo
2. INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION

With increasing concerns about environmental and energy issues in many large Chinese cities, local authorities are introducing public bicycle schemes to promote the use of green transportation modes. This paper proposes a novel model for investigating the effects of the public bicycle schemes in a congested multi-modal road network with auto, bus, and public bicycle travel. The decision-making process of travelers regarding travel modes and route choices is assumed to follow a hierarchical choice structure. The effects of pollution emissions by motorized vehicles (i.e., autos and buses), crowding discomfort in buses, and riding fatigue on bicycles are considered in the proposed model. The multi-modal travel choice equilibrium problem is formulated as an equivalent variational inequality problem. The existence and uniqueness of the solution of the proposed model are examined. A heuristic solution algorithm that combines a diagonalization approach and the method of successive averages is adapted to solve the proposed model. A numerical example is given to illustrate the application of the proposed model and solution algorithm. Findings are reported on the effects of the public bicycle schemes and emission tax policy on the multi-modal transportation system. The optimal public bicycle rental price and emission tax for maximization of social welfare can also be determined by the proposed model.

276. Estimate Passengers' Walking and Waiting Time in Metro Station Using Smart Card Data (SCD)

1. Li, Wanjun; Yan, Xuedong; Li, Xiaomeng; Yang, Jingsi
2. IEEE ACCESS

Passengers' walking time and waiting time at metro stations are important indicators for evaluating the level of service (LOS) of a metro station. This paper aims to estimate passengers' walking time and waiting time at metro stations based on a proposed passenger-to-train assignment method using smart card data (SCD). Firstly, two algorithms were developed to determine the possible train choice set for all the passengers. Secondly, passengers' walking time distribution was estimated for different group of passengers categorized by travel periods, type of cardholder and social demographics. Lastly, passengers' waiting time at origin stations was explored based on the train choice model proposed in this study. The study found that passengers traveling at peak hours tend to walk faster than they do at non-peak hours. The overall waiting time at origin stations is highly related to the train headway (time interval between the adjacent arrival trains in the same direction and station) and passenger volume. More importantly, the result suggested when the passenger volume is low, train headway could significantly affect waiting time. However, when the passenger volume exceeds certain level (>1000 in 15 minutes), it becomes to the major factor leading to the increase in waiting time. Elders and disabled passengers have extended waiting time during peak hours than other passengers. The method proposed in this study offers a new perspective of using SCD in travel behavior analysis. Besides, the results bring insights for future metro station construction and operation design as well as evaluation on the LOS of metro system.

277. 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. NETWORKS & SPATIAL ECONOMICS

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).

278. Time-Dependent Intermodal A* Algorithm: Methodology and Implementation on a Large-Scale Network

1. Verbas, Omer; Auld, Joshua; Ley, Hubert; Weimer, Randy; Driscoll, Shon
2. TRANSPORTATION RESEARCH RECORD

This paper proposes a time-dependent intermodal A* (TDIMA*) algorithm. The algorithm works on a multimodal network with transit, walking, and vehicular network links, and finds paths for the three major modes (transit, walking, driving) and any feasible combination thereof (e.g., park-and-ride). Turn penalties on the vehicular network and progressive transfer penalties on the transit network are considered for improved realism. Moreover, upper bounds to prevent excessive waiting and walking

are introduced, as well as an upper bound on driving for the park-and-ride (PNR) mode. The algorithm is validated on the large-scale Chicago Regional network using real-world trips against the Google Directions API and the Regional Transit Authority router.

279. Passenger arrival and waiting time distributions dependent on train service frequency and station characteristics: A smart card data analysis

1. Ingvardson, Jesper Blafoss; Nielsen, Otto Anker; Raveau, Sebastian; Nielsen, Bo Friis
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

Waiting time at public transport stops is perceived by passengers to be more onerous than in vehicle time, hence it strongly influences the attractiveness and use of public transport. Transport models traditionally assume that average waiting times are half the service headway by assuming random passenger arrivals. However, research agree that two distinct passenger behaviour types exist: one group arrives randomly, whereas another group actively tries to minimise their waiting time by arriving in a timely manner at the scheduled departure time. This study proposes a general framework for estimating passenger waiting times which incorporates the arrival patterns of these two groups explicitly, namely by using a mixture distribution consisting of a uniform and a beta distribution. The framework is empirically validated using a large-scale automatic fare collection system from the Greater Copenhagen Area covering metro, suburban, and regional rail stations thereby giving a range of service headways from 2 to 60 min. It was shown that the proposed mixture distribution is superior to other distributions proposed in the literature. This can improve waiting time estimations in public transport models. The results show that even at 5-min headways 43% of passengers arrive in a timely manner to stations when timetables are available. The results bear important policy implications in terms of providing actual timetables, even at high service frequencies, in order for passengers to be able to minimise their waiting times.

280. Mixed-integer programming model and branch-and-price-and-cut algorithm for urban bus network design and timetabling

1. Chu, James C.
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This study solves the simultaneous planning problem of network design and timetabling for urban bus systems. An innovative mixed-integer programming (MIP) model is formulated and a parallel branch-and-price-and-cut (BPC) algorithm is proposed to solve the problem. The key idea of the model formulation and the solution algorithm is to represent a bus timetable with a route and a dispatch pattern. An aggregation and greedy algorithm is developed to efficiently solve the pricing subproblem. The cuts of disaggregate coupling inequalities are dynamically added to strengthen the lower bound. A computational study is conducted to evaluate the performance of the proposed methodology. The comparison with alternative solution approaches indicates that the parallel BPC algorithm is superior to solving the MIP formulations with the off-the-shelf MIP solver. Different values of model parameters are also tested, and various statistics of operators and passengers are reported for the cases. (C) 2017 Elsevier Ltd. All rights reserved.

281. The design of coastal shipping services subject to carbon emission reduction targets and state subsidy levels

1. Chen, Kang; Yang, Zhongzhen; Notteboom, Theo

2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

This paper presents a New Coastal Liner Route Design Model (NCLRDM) for coastal intermodal networks based on the user equilibrium assignment model (UE model). The NCLRDM can determine ports of call, call sequence, ship type and service frequency simultaneously with the objective of minimizing state subsidies for coastal shipping operators under a given carbon emission reduction target for the entire intermodal network. A network-topology method (Temporal-Spatial Expansion) captures differences in traffic assignment between waterway and highway networks. A genetic and Frank-Wolfe hybrid algorithm is used to solve the NCLRDM. The model is applied to the Bohai Bay in China. (C) 2013 Elsevier Ltd. All rights reserved.

282. Modelling the effects of real-time crowding information in urban public transport systems

1. Drabicki, Arkadiusz; Kucharski, Rafal; Cats, Oded; Szarata, Andrzej
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

Public transport (PT) overcrowding is a notorious problem in urban transport networks. Its negative effects upon travel experience can be potentially addressed by disseminating real-time crowding information (RTCI) to passengers. However, impacts of RTCI provision in urban PT networks remain largely unknown. This study aims to contribute by developing an extended dynamic PT simulation model that enables a thorough analysis of instantaneous RTCI consequences. In the model, RTCI is generated and disseminated across the network, and then utilised in passengers' sequential en-route choices. A case-study demonstration of the RTCI algorithm on urban PT network model of Krakow (Poland) shows that instantaneous RTCI has the potential to improve passengers' travel experience, although it is also susceptible to inaccuracy. RTCI provision can yield total travel utility improvements of 3% in typical PM peak-hour, with reduced impacts of the worst overcrowding effects (in terms of denied-boarding and in-vehicle travel disutility in overcrowded conditions) of 30%. Highlights: Real-time crowding information (RTCI) is an increasingly feasible solution in public transport. We introduce a novel framework for modelling the network effects of instantaneous RTCI. Instantaneous RTCI can result in improved travel experience but also substantial inaccuracy risk. Reduced impacts of the worst overcrowding experience amount to up to 30%.

283. Scheduling zonal-based flexible bus service under dynamic stochastic demand and Time-dependent travel time

1. Lee, Enoch; Cen, Xuekai; Lo, Hong K.
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

This paper schedules the zonal-based flexible bus service (ZBFBS) considering elastic stochastic demand, stochastic location, time-dependent travel time, and passenger time window constraints based on a scheduled-based formulation. Unlike a traditional time-space network that stipulates the precise arrival and departure times on specific nodes, a zonal-based time-space network is proposed to define the routes in terms of zonal visits of the flexible buses while allowing for flexibility in their arrival and departure times to cater for randomness. The ZBFBS scheduling problem is formulated as a two-stage decision-dependent stochastic problem with recourse. The first stage schedules the zonal visits of flexible buses and the second stage matches each passenger with either flexible bus or ad hoc service, with the latter incurring extra cost to carry the un-matched passengers. To effectively solve the

problem, a state-augmented network, that integrates time and zone, is proposed to reduce the number of variables. Moreover, relaxation formulations based on vehicle types and routes are introduced, with an insertion heuristic implemented for vehicle scheduling. The problem is solved by a gradient-based solution approach. Numerical studies demonstrate the efficiency and quality of the solution methods under a variety of ride requests, as well as its advantage over the frequency-based approach in substantially reducing the ad hoc service cost. The applicability of the model is validated by solving an instance of Chengdu, China, with real data.

284. Large-scale multimodal transportation network models and algorithms-Part I: The combined mode split and traffic assignment problem

1. Fan, Yinchao; Ding, Jianxun; Liu, Haoxiang; Wang, Yu; Long, Jiancheng
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

Modelling the combined mode split and traffic assignment (CMSTA) problem is essential to capture the travelers' behaviors and predict the flow distribution in multimodal transportation networks. In this paper, a general fixed-point model that combines the CNL-based mode split and the VI-based traffic assignment is developed to formulate the CMSTA problem in a more realistic multimodal network. The transit common line problem and asymmetric travel cost are considered. A new solution algorithm that integrated with several effective methods and strategies is proposed to solve the fixed-point model in large-scale networks. Numerical results show the effectiveness of the proposed model and algorithm.

285. Can passenger flow distribution be estimated solely based on network properties in public transport systems?

1. Luo, Ding; Cats, Oded; van Lint, Hans
2. TRANSPORTATION

We present a pioneering investigation into the relation between passenger flow distribution and network properties in public transport systems. The methodology is designed in a reverse engineering fashion by utilizing passively measured passenger flow dynamics over the entire network. We quantify the properties of public transport networks using a range of centrality indicators in the topological representations of public transport networks with both infrastructure and service layers considered. All the employed indicators, which originate from complex network science, are interpreted in the context of public transport systems. Regression models are further developed to capture the correlative relation between passenger flow distribution and several centrality indicators that are selected based on the correlation analysis. The primary finding from the case study on the tram networks of The Hague and Amsterdam is that the selected network properties can indeed be used to approximate passenger flow distribution in public transport systems to a reasonable extent. Notwithstanding, no causality is implied, as the correlation may also reflect how well the supply allocation caters for the underlying demand distribution. The significance and relevance of this study stems from two aspects: (1) the unraveled relation provides a parsimonious alternative to existing passenger assignment models that require many assumptions on the basis of limited data; (2) the resulting model offers efficient quick-scan decision support capabilities that can help transport planners in tactical planning decisions.

286. Bus timetabling considering passenger satisfaction: An empirical study in Beijing

1. Shang, Hua-Yan; Huang, Hai-Jun; Wu, Wen-Xiang
2. COMPUTERS & INDUSTRIAL ENGINEERING

Public transport is the key component in sustainable transportation. In China, large subsidies are provided by the national and local governments to encourage the use of public transport systems. However, high commuting demand leads to such incredible phenomenon that passengers have to climb windows for riding in buses during peak hours. Thus, a case study was conducted in a Beijing's transport hub which covers 116 bus lines and ten stations. The existing bus timetabling is surprisingly manually made and 26.53% of the bus supply undertakes 59.19% of the bus demand, which results in unbearable long waiting time and on-board crowding. To find a bus timetabling method which is practical and applicable in China, three procedures are carried out. Firstly, the passenger satisfaction and the bus transit efficiency are simplified and formulated. Secondly, a preliminary bus timetabling method with consideration of passenger satisfaction is proposed for optimizing the bus frequency and headway. Thirdly, the bus timetabling is optimized by embodying a balance between the passenger satisfaction and the bus transit efficiency, subject to the constraints of load factor. This method is verified by field data and the results demonstrate that it has the advantage of reducing waiting time and lessening on-board discomfort.

287. Personalized predictive public transport crowding information with automated data sources

1. Jenelius, Erik

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

The paper proposes a methodology for providing personalized, predictive in-vehicle crowding information to public transport travellers via mobile applications or at-stop displays. Three crowding metrics are considered: (1) the probability of getting a seat on boarding, (2) the expected travel time standing, and (3) the excess perceived travel time compared to uncrowded conditions. The methodology combines prediction models of passenger loads and alighting counts based on lasso regularized regression and multivariate PLS regression, a probabilistic seat allocation model and a bias correction step in order to predict the crowding metrics. Depending on data availability, the prediction method can use a combination of historical passenger counts, real-time vehicle locations and real-time passenger counts. We evaluate the prediction methodology in a real-world case study for a bus line in Stockholm, Sweden. The results indicate that personalized, predictive crowding information that is robust to varying data availability can be provided sufficiently early to be useful to travellers. The methodology is of value for agencies and operators in order to increase the attractiveness and capacity utilization of public transport.

288. Route choice and assignment

1. Ceder, Avishai (Avi)

2. PUBLIC TRANSIT PLANNING AND OPERATION: MODELING, PRACTICE AND BEHAVIOR, 2ND EDITION

nan

289. Equilibrium network design of shared-vehicle systems

1. Nair, Rahul; Miller-Hooks, Elise

2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

An equilibrium network design model is formulated to determine the optimal configuration of a vehicle sharing program (VSP). A VSP involves a fleet of vehicles (bicycles, cars, or electric vehicles)

positioned strategically across a network. In a flexible VSP, users are permitted to check out vehicles to perform trips and return the vehicles to stations close to their destinations. VSP operators need to determine an optimal configuration in terms of station locations, vehicle inventories, and station capacities, that maximizes revenue. Since users are likely to use the VSP resources only if their travel utilities improve, a generalized equilibrium based approach is adopted to design the system. The model takes the form of a bi-level, mixed-integer program. Model properties of uniqueness, inefficiency of equilibrium, and transformations that lead to an exact solution approach are presented. Computational tests on several synthetic instances demonstrate the nature of the equilibrium configuration, the trade-offs between operator and user objectives, and insights for deploying such systems. (C) 2014 Published by Elsevier B.V.

290. Understanding the route choice behaviour of metro-bikeshare users

1. Liu, Yang; Feng, Tao; Shi, Zhuangbin; He, Mingwei
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

Understanding the determinants of the route choice behaviour on a multi-modal transit network of metro and shared bike is important to improve personalized multimodal travel services. This paper attempts to analyse the route choice behaviour of metro-bikeshare users considering passengers' socio-economic attributes and perceived congestion which is approximated by load status. An abstract integrated metro-bikeshare network (IMBN) is built with virtual nodes by aggregating shared bike stations within the walkable distance and abstract routes by aggregating optional paths for each OD pair. Using the metro- and shared bike smart- card data from Nanjing, China, the route sets of metro-bikeshare users were extracted from the IMBN. A multinomial Logit model (MNL) was then applied to investigate the determinants of route choice behaviour for two types of users, namely return-enter and exit-lease, respectively. The results show that the models with the load status attributes have a better performance than the models without these attributes. We found the sensitivity of exit-lease users to the train crowding is significantly greater than that of the return-enter users. Return-enter users have a higher perception of out - of-vehicle travel time (OVTT) than that of in-vehicle travel time (IVT), while the exit-lease users have the opposite perception. Besides, the change rate of shared bike inventory, departure time and whether he or she is a regular user also have a significant impact on route choice behaviour. The findings can help policymakers and system operators to improve the services and the efficiency of the multimodal transportation system.

291. Stochastic bus schedule coordination considering demand assignment and rerouting of passengers

1. Wu, Weitiao; Liu, Ronghui; Jin, Wenzhou; Ma, Changxi
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Schedule coordination is a proven strategy to improve the connectivity and service quality for bus networks, whereas current research mostly optimizes schedule design using the a priori knowledge of users' routings and ignores the behavioural reactions to coordination status. This study proposes a novel stochastic bus schedule coordination design with demand assignment and passenger rerouting in case of transfer failure. To this end, we develop a bi-level programming model in which the schedule design (headways and slack times) and passenger route choice are determined simultaneously via two travel strategies: non-adaptive and adaptive routings. In the second strategy, transfer passengers would modify their paths in case of missed connection. In this way, the expected network flow

distribution is dependent on both the transfer reliability and network structure. The upper level problem is formulated as a mixed integer non-linear program with the objective of minimizing the total system cost, including both operation cost and user cost, while the lower-level problem is route choice (pre-trip and on-trip) model for timed-transfer service. A more generalized inter-ratio headways scenario is also taken into account. A heuristic algorithm and the method of successive averages are comprehensively applied for solving the bi-level model. Results show that when the rerouting behaviour is considered, more cost-effective schedule coordination scheme with less slack times can be achieved, and ignoring such effect would underestimate the efficacy of schedule coordination scheme. (C) 2019 Elsevier Ltd. All rights reserved.

292. Ex Post Path Choice Estimation for Urban Rail Systems Using Smart Card Data: An Aggregated Time-Space Hypernetwork Approach

1. Mo, Baichuan; Ma, Zhenliang; Koutsopoulos, Haris N.; Zhao, Jinhua
2. TRANSPORTATION SCIENCE

This paper proposes an ex post path choice estimation framework for urban rail systems using an aggregated time-space hypernetwork approach. We aim to infer the actual passenger flow distribution in an urban rail system for any historical day using the observed automated fare collection (AFC) data. By incorporating a schedule-based dynamic transit network loading (SDTNL) model, the framework captures the crowding correlation among stations and the interaction between the path choice and passenger left behind, which is important for the path choice estimation in a near-capacity operated urban rail system. The path choice estimation is formulated as an optimization problem, which aims to minimize the difference between the model-derived and observed information with path choice parameters as decision variables. The original problem is intractable because of nonlinear (logit model) and nonanalytical (SDTNL) constraints. A solution procedure is proposed to decompose the original problem into three tractable subproblems, which can be solved efficiently. Solving the decomposed problem is equivalent to finding a fixed point. We prove that the solution to the original problem is the same as the decomposed problem (i.e., the fixed point) when passenger path choices follow the predefined behavior model. If this condition does not hold, the solution of the

293. Exogenous priority rules for the capacitated passenger assignment problem

1. Binder, Stefan; Maknoon, Yousef; Bierlaire, Michel
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

We propose a novel algorithm for the capacitated passenger assignment problem in public transportation where exogenous priority lists define the order in which passengers are assigned. Separating explicitly these rules from the assignment procedure allows for a great deal of flexibility to model various priority rules. When the actual rules are endogenous, the framework can easily be embedded in a fixed-point specification. Computational experiments are performed on a realistic case study based on the morning rush hours of the timetable of Canton Vaud, Switzerland. The algorithm is able to assign the demand in very low computational times. The results provide evidences that the ordering of the passengers does not have a significant impact on aggregate performance indicators (such as average delay and level of unsatisfied demand), but that the variability at the individual passenger level is substantial. Thanks to its flexibility, our framework can easily be implemented by a railway operator who wishes to evaluate the effects of different policies in terms of passenger priorities. (C) 2017 Elsevier Ltd. All rights reserved.

294. Evacuating metro passengers via the urban bus system under uncertain disruption recovery time and heterogeneous risk-taking behaviour

1. Tan, Zhijia; Xu, Min; Meng, Qiang; Li, Zhi-Chun

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

The bus-bridging service has always faced problems in severe emergencies or catastrophes that require the large-scale evacuation of passengers. This paper provides an alternative evacuation scheme which uses the urban bus network in the case of common metro service disruptions; this is modeled by minimizing the total cost of the affected metro passengers, through jointly selecting the bus lines and frequencies. The uncertain recovery time of the service disruption and the heterogeneous risk-taking behavior of the affected metro passengers are incorporated in the scheme. Therefore, we build a linkage between the evacuation service design and the risk-taking behavior of passengers. A heuristic algorithm is proposed to calculate the optimal evacuation scheme. A numerical experiment using a real-world network is conducted to illustrate the validity of the model and algorithm.

295. A Schedule-Based Model for Passenger-Oriented Train Planning With Operating Cost and Capacity Constraints

1. Xie, Jiemin; Zhan, Shuguang; Wong, Sze Chun; Lo, Siu Ming

2. IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS

In the planning stage, train operators design timetables to serve passenger trips and a train circulation plan to support these timetables. These designs consider not only operating costs but also passenger convenience. In this study, we developed an optimization model for a new problem that focuses on timetabling and train-unit scheduling while also considering passenger itinerary choices in a schedule-based train system. This optimization model minimizes passenger travel costs within the constraints of a limited budget available for operating costs. The model is solved by an iterative heuristic that simulates the interaction between train operations and passenger itinerary choices. The heuristic solves the timetabling and train-unit scheduling problem using a decomposition approach to increase computational efficiency, while passenger loading is solved by a user-equilibrium passenger assignment model. An example based on the high-speed railway network in southern China was used to demonstrate the effectiveness of the proposed model and method.

296. Railway delay management with passenger rerouting considering train capacity constraints

1. Koenig, Eva; Schoen, Cornelia

2. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

Delay management for railways is concerned with the question of whether a train should wait for a delayed feeder train or depart on time. The answer should not only depend on the length of the delay but also consider other factors, such as capacity restrictions. We present an optimization model for delay management in railway networks that accounts for capacity constraints on the number of passengers that a train can effectively carry. While limited capacities of tracks and stations have been considered in delay management models, passenger train capacity has been neglected in the literature so far, implicitly assuming an infinite train capacity. However, even in open systems where no seat reservation is required and passengers may stand during the journey if all seats are occupied, physical space is naturally limited, and the number of standing seats is constrained for passenger safety

reasons. We present a mixed-integer nonlinear programming formulation for the delay management problem with passenger rerouting and capacities of trains. Our model allows the rerouting of passengers missing their connection due to delays or capacity constraints. We linearize the model in exact and approximate ways and experimentally compare the different approaches with the solution of a reference model from the literature that neglects capacity constraints. The results demonstrate that there is a significant impact of considering train capacity restrictions in decisions to manage delays. (C) 2020 Elsevier B.V. All rights reserved.

297. Quantifying Factors Influencing Urban Bus Passenger Boarding and Alighting Dynamics in an Emerging Economy

1. Dandapat, Saurabh; Bhattacharyya, Kinjal; Maitra, Bhargab
2. JOURNAL OF TRANSPORTATION ENGINEERING PART A-SYSTEMS

A majority of the past studies on bus dwell time have been carried out in the context of developed countries, and the dwell time prediction models established in literature adopted the fixed-parameter assumption. The variations due to human factors such as passenger and driver behavior are not reflected under a fixed-parameter framework. This paper presents a methodology for rational estimation of passenger boarding and alighting time in the context of an emerging country using both fixed-parameter and random-parameter models. The methodology was demonstrated with a case study in the Kolkata metro area of India. The results established that the boarding and alighting time varies significantly across bus type, in-vehicle crowding, and size of the passenger group. In this context, random-parameter models were found to outperform fixed-parameter models in capturing the heterogeneity in bus and demand characteristics. The models were validated successfully with statistically acceptable errors.

298. An Accurate Collaborative Programming Model of Passenger Flow Control for an Oversaturated Metro Network

1. Wang, Peiheng
2. IEEE ACCESS

To reduce potential accident risks and unnecessary time wasting, passenger flow control measures have been widely adopted for metro lines with oversaturated passenger flow. This paper proposes an integer linear programming (ILP) formulation for the optimal coordination of a passenger-oriented flow control strategy in a metro network during peak hours. The objective function of our formulation minimizes the total passenger waiting time at all stations under the premise of guaranteeing safety inside transfer stations. Our ILP formulation simultaneously considers the time-dependent passenger demand, destinations of the boarding passengers, transfer processes and train loading capacity constraints on lines in a metro network. Based on an upper bound on the number of waiting passengers at each station, a linear dynamic proportional method for assigning destinations for the boarding passengers is derived. Moreover, the method maintains the fast convergence of our ILP formulation and lets the formulation support real-time decision-making. Finally, a real-world instance with operation data of the Beijing metro system is implemented to demonstrate the accurate control ability to passenger flow of the proposed approach. As a result, the formulation obtains a solution with a total passenger waiting time of 57,488 min at transfer stations, which is 6698 min less than the value that is obtained with the previously established passenger flow control scheme.

299. Impacts of real-time information levels in public transport: A large-scale case study using an adaptive passenger path choice model

1. Paulsen, Mads; Rasmussen, Thomas Kjaer; Nielsen, Otto Anker
2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

Public transport services are often uncertain, causing passengers' travel times and routes to vary from day to day. However, since door-to-door passenger delays depend on both intended and realised routes, they are difficult to calculate, as opposed to vehicle delays which can be derived directly from the widely available Automated Vehicle Location (AVL) data of the public transport system. In this study we use three months of such historical AVL data to calculate corresponding realised routes and passengers delays in a large-scale, multi-modal transport network by formulating and implementing an adaptive passenger path choice model in an agent-based scenario of Metropolitan Copenhagen with 801,719 daily trips. The proposed model allows analysing five different levels of real-time information provision, ranging from no information at all to global real-time information being available everywhere. The results of more than 258 million (positive or negative) passenger delays show that variability of passengers' travel time is considerable and much larger than that of the public transport vehicles. It is also shown that obtaining global real-time information at the beginning of the trip reduces passengers delay dramatically, although still being inferior to receiving such along the trip. Additionally, being able to automatically obtain real-time passenger information while walking and being on-board public transport services is found not to lead to considerable improvements compared to acquiring such information manually while waiting at stops, although slight benefits are demonstrated in supplementary models run with pseudo-intelligent vehicle delay forecasting.

300. One-to-many matching and section-based formulation of autonomous ridesharing equilibrium

1. Noruzoliaee, Mohamadhossein; Zou, Bo
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

This paper models autonomous ridesharing - multiple travelers simultaneously riding one shared autonomous vehicle (SAV) - in a network equilibrium setting with mixed SAV and human-driven vehicle (HV) traffic. We make two major methodological contributions. First, a novel one (SAV)-to-many (riders) matching is proposed to characterize the waiting times of an SAV and multiple travelers who share rides in the SAV during online matching, which is a nontrivial generalization of the one-to-one matching without ridesharing. Our matching characterization considers the possibilities of a traveler matched with an SAV starting from the same origin, whereto the SAV moved unoccupied as a result of either pickup or relocation, or with an in- service SAV that goes through the traveler's origin. Second, a section-based formulation for SAV ridesharing user equilibrium is introduced to characterize the SAV traveler flow, which accom-modates the possibility that an SAV traveler's itinerary (OD pair) is different from that of the serving SAV and other travelers in the SAV. Unlike the existing link and route based ridesharing formulations, the notion of section both prevents undesired traveler en-route transfer(s) and al-lows travelers of multiple ODs to share rides, meanwhile respecting the SAV seat capacity constraint. In addition to the above two methodological contributions, the optimal SAV fleet size, fare, routing, and allocation (to in-service, pickup, and relocation states) decisions of a trans- portation network company (TNC) are formulated. The TNC decisions anticipate traveler re-actions as characterized by a new multimodal autonomous ridesharing user equilibrium (MARUE), which is put forward with a proof of its existence and finds the endogenous market shares and road congestion

effects of SAV/HV. Original insights are obtained from model implementation, including substantial systemwide benefit of ridesharing, marginal benefit of relocation in the presence of ridesharing, and diminishing economies of SAV size.

301. Passenger Perspectives in Railway Timetabling: A Literature Review

1. Parbo, Jens; Nielsen, Otto Anker; Prato, Carlo Giacomo
2. TRANSPORT REVIEWS

When looking at railway planning, a discrepancy exists between planners who focus on the train operations and publish fixed railway schedules, and passengers who look not only at the schedules but also at the entirety of their trip, from access to waiting to on-board travel and egress. Looking into this discrepancy is essential, as assessing railway performances by merely measuring train punctuality would provide an unfair picture of the level of service experienced by passengers. Firstly, passengers' delays are often significantly larger than the train delays responsible for the passengers to be late. Secondly, trains' punctuality is often strictly related to too tight schedules that in turn might translate into knock-on delays for longer dwelling times at stations, trip delays for increased risk of missing transfer connections, and uncertain assessment of the level of service experienced, especially with fluctuating passenger demand. A key aspect is the robustness of railway timetables. Empirical evidence indicates that passengers give more importance to travel time certainty than travel time reductions, as passengers associate an inherent disutility with travel time uncertainty. This disutility may be broadly interpreted as an anxiety cost for the need for having contingency plans in case of disruptions, and may be looked at as the motivator for the need for delay-robust railway timetables. Interestingly, passenger-oriented optimisation studies considering robustness in railway planning typically limit their emphasis on passengers to the consideration of transfer maintenance. Clearly, passengers' travel behaviour is far more complex and multi-faceted and thus several other aspects should be considered, as becoming more and more evident from passenger surveys. The current literature review starts by looking at the parameters that railway optimisation/planning studies are focused on and the key performance indicators that impact railway planning. The attention then turns to the parameters influencing passengers' perceptions and travel experiences. Finally, the review proposes guidelines on how to reduce the gap between the operators' railway planning and performance measurement on the one hand and the passengers' perception of the railway performance on the other hand. Thereby, the conclusions create a foundation for a more passenger-oriented railway timetabling ensuring that passengers are provided with the best service possible with the resources available.

302. Tailored Wakeby-type distribution for random bus headway adherence ratio

1. Zhang, Man; Meng, Qiang; Kang, Liujiang; Li, Wenquan
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper addresses an interesting and practical bus headway adherence issue for a given public bus route with a number of bus stops. It first defines the random headway adherence ratio (HAR) at a particular bus stop of a specific bus route as the ratio of difference between actual bus headway and scheduled headway with respect to the scheduled headway. This study proceeds to customize a four-step procedure to estimate a probability distribution that can describe the random HAR at each bus stop of the bus route by using the automatic vehicle location (AVL) data. Our real case studies with 44,025 HAR data show that the 19 existing probability distributions including Lognormal, Gamma, Beta and Wakeby are unable to well fit these HAR data. This study thus proposes a tailored Wakeby-type

distribution with five parameters. After deriving two fundamental propositions for the tailored Wakeby-type distribution, a tangible L-moment based method to estimate those parameters involved the tailored Wakeby distribution is presented. The tailored Wakeby-type distributions can meet our expectation via our real case studies. Finally, applications of the tailored Wakeby-type distribution derived for the random HAR are conducted.

303. A new solution framework for the limited-stop bus service design problem

1. Soto, Guillermo; Larrain, Homero; Carlos Munoz, Juan
2. TRANSPORTATION RESEARCH PART B-METHODOLOGICAL

Limited-stop services are a key element to the successful operation of bus rapid transit corridors. In this study, we present a framework for addressing the limited-stop service design problem over a corridor, and formally introduce a family of subproblems involved in its solution. Using a bi-level optimization approach, we introduce a method of designing these services while considering bus capacity, transfers, and two behavioral models for passengers: deterministic and stochastic. The algorithm and its variants were tested on nine scenarios with up to 80 stops. Working with deterministic passenger assignment, our model solved the problem in a small fraction of the time required by a benchmark algorithm. We use this algorithm to show that neglecting transfers can lead to suboptimal solutions. We finally show that although it makes the problem much harder, working with stochastic assignment leads to more realistic and robust solutions. (C) 2017 Elsevier Ltd. All rights reserved.

304. Network equilibrium for congested multi-mode networks with elastic demand

1. Wu, ZX; Lam, WHK
2. JOURNAL OF ADVANCED TRANSPORTATION

This paper proposes an elastic demand network equilibrium model for networks with transit and walking modes. In Hong Kong, the multi-mode transit system services over 90% of the total journeys and the demand on it is continuously increasing. Transit and walking modes are related to each other as transit passengers have to walk to and from transit stops. In this paper, the multi-mode elastic-demand network equilibrium problem is formulated as a variational inequality problem where the combined mode and route choices are modeled in a hierarchical logit structures and the total travel demand for each origin-destination pair is explicitly given by an elastic demand function. In addition, the capacity constraint for transit vehicles and the effects of bi-directional flows on walkways are considered in the proposed model. All these congestion effects are taken into account for modeling the travel choices. A solution algorithm is developed to solve the multi-mode elastic-demand network equilibrium model. It is based on a Block Gauss-Seidel decomposition approach coupled with the method of successive averages. A numerical example is used to illustrate the application of the proposed model and solution algorithm.

305. Dynamic passenger demand-oriented train scheduling optimization considering flexible short-turning strategy

1. Yang, Liya; Yao, Yu; Shi, Hua; Shang, Pan
2. JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY

In this study, we focus on improving the efficiency of an urban rail transit line under the circumstance of spatially unbalanced passenger demand. A flexible short-turning strategy is integrated into the train

scheduling problem, aiming to obtain a train timetable and the corresponding circulation plan adapted to a time-dependent passenger demand. First, we formulate the dynamic passenger demand-oriented train scheduling problem as a multi-commodity network flow optimization model in a two-layer space-time network. The proposed model is then decomposed into train scheduling and passenger assignment sub-problems by relaxing the coupling constraint. Therefore, an optimal solution of the original model can be obtained by iteratively solving two easy-to-solve sub-problems in a Lagrangian relaxation solution framework. The effectiveness of the model is evaluated using a series of simple experiments and a real-world case study based on the Beijing Yizhuang Line.

306. Data-driven approach for solving the route choice problem with traveling backward behavior in congested metro systems

1. Yu, Chao; Li, Haiying; Xu, Xinyue; Liu, Jun

2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

This study proposes a data-driven approach to understand traveling backward (TB) behavior while making a route choice in congested metros. First, TB behavior during route choice in overcrowded metros is defined and analyzed. Second, a hybrid model comprising three hierarchical Bayesian models is developed to describe the TB behavior. Third, a novel sampling method based on Hamiltonian dynamics is introduced to estimate the model parameters. Finally, a case study of Beijing metro is discussed to illustrate the effectiveness and robustness of the proposed model. The contributions of application of the proposed model to accurate demand assignment and passenger flow control for metro managers are demonstrated.

307. A passenger-pedestrian model to assess platform and train usage from automated data

1. Hanseler, Flurin S.; van den Heuvel, Jeroen P. A.; Cats, Oded; Daamen, Winnie; Hoogendoorn, Serge P.

2. TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE

We present a transit model that, based on automated fare collection and train tracking data, describes pedestrian movements in train stations and vehicle-specific train ridership distributions. Our approach differs from existing models in that we describe on-board passenger dynamics and pedestrian dynamics at stations in a joint framework. We assume that travelers first decide on the train(s) they will take, and then pursue their journey through the network by successively choosing pedestrian paths, waiting positions on platforms, and specific train cars. Travelers explicitly maximize their travel utility. We model how crowding influences their walking speeds, and how it affects travel utility both at stations and on-board. To illustrate the framework, we present a real case study of a major Dutch rail corridor, for which we collect a rich set of passenger, pedestrian and train operation data. We observe a good agreement of model estimates with empirical observations, and discuss the use of the model for various transit-related problems including level-of-service assessment, crowding estimation, transit optimization, and integrated investment appraisal.

308. Route guidance ranking procedures with human perception consideration for personalized public transport service

1. Ceder, Avishai (Avi); Jiang, Yu

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

The use of smartphone applications (apps) to acquire real time and readily available journey planning information is becoming instinctive behavior by public transport (PT) users. Through the apps, a passenger not only seeks a path from origin to destination, but a satisfactory path that caters to the passenger's preferences at the desired time of travel. Essentially, apps attempt to provide a means of personalized PT service. As the implications of the Covid-19 pandemic take form and infiltrate human and environmental interactions, passenger preference personalization will likely include avoiding risks of infection or contagious contact. The personal preferences are enabled by multiple attributes associated with alternative PT routes. For instance, preferences can be connected to attributes of time, cost, and convenience. This work establishes a personalized PT service, as an adjustment to current design frameworks, by integrating user app experience with operators' data sources and operations modeling. The work proceeds to focus on its key component: the personalized route guidance methodology. In addition to using the existing shortest path or k -weighted shortest path method, this study develops a novel, lexicographical shortest path method, considering a just noticeable difference (JND). The method adopts lexicographical ordering to capture passenger preferences for different PT attributes following Ernst Weber's law of human perception threshold. However, a direct application of Weber's law violates the axiom of transitivity required for an implementable algorithm, and thus, a revised method is developed with proven algorithms for ranking different paths. The differences between the three route-guidance methods and the effects of the JND perception threshold on the order of the alternative PT routes are demonstrated with an example. The developments were examined in a case study by simulation on the Copenhagen PT network. The results show that using the JND method reduces the value/cost of the most important attributes. Identical robust results are attained when JND parameters are not specified and default values are used. The latter may apply for the future with a mixture of specified and default preference input values. Finally, the computation time indicates a favorable potential for real-life applications. It is believed that the consideration of human threshold perception will encourage decision makers to establish new criteria to comply with this.

309. Probabilistic assessment of transport network vulnerability with equilibrium flows

1. Jiang, Yu; Wang, Yi; Szeto, W. Y.; Chow, Andy H. F.; Nagurney, Anna
2. INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION

This article develops a probabilistic approach for assessing transport network vulnerability. A novel performance measure is proposed to evaluate the expected impact when multiple transport network components fail simultaneously at various degrees. The proposed measure captures both the likelihood and consequence of a combination of transport network component failures. The most critical combination of transport network component failures is obtained by solving a bi-level optimization problem. The upper-level problem is to solve for the combination of transport network components together with their corresponding disruption levels, which induces the maximum reduction in the performance measure. The lower-level problem is to capture the response of travelers to network changes due to network component failures and is formulated as a traffic assignment problem. The clonal selection algorithm (CSA), a biologically inspired approach, is adopted to tackle the proposed bi-level optimization problem. Numerical results indicate that neglecting partial capacity degradation and its probability of occurrence could misestimate the worst scenario, and different vulnerability assessment approaches could identify similar critical components but our approach can discover some components that are not found by other existing approaches. Moreover, it is shown that the CSA outperforms the well-known genetic algorithm in terms of solution quality in a large network.

310. STOCHASTIC MULTI-MODAL TRANSPORT NETWORK UNDER DEMAND UNCERTAINTIES AND ADVERSE WEATHER CONDITION

1. Sumalee, Agachai; Uchida, Kenetsu; Lam, William H. K.
2. 18TH INTERNATIONAL SYMPOSIUM ON TRANSPORTATION AND TRAFFIC THEORY

This paper proposes a novel multi-modal transport network assignment model considering uncertainties in both demand and supply sides of the network. These uncertainties are mainly due to adverse weather conditions with different degrees of impacts on different modes. The paper provides the derivation of mean and variance-covariance of 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 an average and uncertainty of the random perceived travel time on each multi-modal path in their path choice decisions. The model also considers travelers' perception errors using a Probit stochastic user equilibrium framework formulated as fixed point problem. A heuristic solution algorithm is proposed for solving the fixed point problem. Numerical examples are presented to illustrate the applications of the proposed model.

311. Long-Distance-Commuter (LDC) Lane: A New Concept for Freeway Traffic Management

1. Qu, Xiaobo; Wang, Shuaian
2. COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

Many freeways connect two major cities (e.g., Gold Coast to Brisbane) in Australia. A great portion of commuters travel between these two cities whereas the number of commuters taking the on-ramps and off-ramps in between is comparatively small. Enlightened by this observation, we propose a novel and practical concept for freeway traffic management: long-distance-commuter (LDC) lane. The LDC lane is a dedicated lane that only commuters traveling between the two major cities can use. Since there is no or only minor disturbance from forced lane-changing of vehicles from other lanes, the LDC lane admits a much higher capacity. Our preliminary case study based on the freeway between Gold Coast and Brisbane demonstrates that using the LDC lane significantly increases the average speed as well as overall capacity.

312. Optimizing Passenger Flow Control and Bus-Bridging Service for Commuting Metro Lines

1. Yang, Jingfeng; Jin, Jian Gang; Wu, Jianjun; Jiang, Xi
2. COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

Oversaturated conditions are often observed during peak-hour periods, especially for commuting metro lines serving as a corridor connecting suburb and urban areas due to its unidirectional passenger flow pattern. System operators are concerned about the amount of passengers accumulated inside station and at platform when train service cannot meet the travel demand. In this article, we tackle the metro system congestion issue and develop a compound strategy integrating passenger flow control and bus-bridging service, to mitigate overcrowded situation. A two-stage mathematical modeling procedure is proposed. Stage 1 determines the stations and time periods for taking passenger flow control strategy. Stage 2 identifies the optimal bus-bridging services. Mixed integer linear programming models are developed to find the demand-responsive flow control pattern and bus-bridging services. The proposed passenger flow control and bus-bridging strategy is applied to a commuting metro line in Shanghai. The results show that the proposed strategy is effective in reducing

the number of stranded passengers, releasing the overcrowding pressure, and improving passengers' satisfaction.

313. A reliability-based assignment method for railway networks with heterogeneous passengers

1. Xu, Guangming; Liu, Wei; Yang, Hai
2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

Travel reliability can play an important role in shaping travelers' route choice behavior. This paper develops a railway passenger assignment method to capture the reliability-based route choices, where the trains can have stochastic delays. The overall travel reliability has two components: the travel time reliability (of trains) and the associated transfer reliability (of connections). In this context, mean-and-variance-based effective travel cost is adopted to model passengers' evaluation of different travel options in the railway network. Moreover, passengers are heterogeneous as they may evaluate the effective travel cost differently, and they may have different requirements for the successful transfer probability (if transfers are involved in the trip). The determination of travel time reliability (of trains) is based on the travel delay distribution, and the successful transfer probability is calculated based on the delay probabilities of two trains in the transfer process. An algorithm has been designed for solving the model, and numerical examples are presented to test and illustrate the model.

314. Agent-based day-to-day adjustment process to evaluate dynamic flexible transport service policies

1. Djavadian, Shadi; Chow, Joseph Y. J.
2. TRANSPORTMETRICA B-TRANSPORT DYNAMICS

Advances in information and communications technologies, connected vehicle technologies, and Big Data have made it viable for public agencies to offer efficient flexible transit services for travel demand that is predominantly dynamic to the system. There is a clear gap in methodologies to evaluate the user equilibrium for flexible transport services (FTS). In this study we lay the groundwork for studying the equilibrium of these systems and propose an agent-based adjustment process to evaluate the properties of a stable state as an agent-based stochastic user equilibrium. To validate the proposed process and illustrate its effectiveness in measuring the effect of changes in FTS operating parameters on ridership three sets of experiments are conducted: (1) illustration with a simple 2-link network, (2) evaluation of a dynamic dial-a-ride problem, and (3) illustration using real data from Oakville, Ontario consisting of 57 zones and 2000 commuters.

315. Equilibrium analysis of mixed passengers in urban railway network

1. Zhang Lu; Wu Jian-jun; Sun Hui-jun
2. JOURNAL OF CENTRAL SOUTH UNIVERSITY

A model is proposed to describe the passengers' route choice behaviors in urban railway traffic with stochastic link capacity degradation by considering two types of demand, sensitive and insensitive passenger. The insensitive passengers choose their route without paying much attention to congestion. To the contrary, sensitive passengers who consider route congestion choose travel route based on generalized cost. An equilibrium state is given by variational inequalities in terms of travel generalized cost, which is represented by the combinations of mean and variance of total travel time. The

diagonalization algorithm is given to solve this programming. Results show that insensitive passengers have large effects on the path choice than sensitive ones, especially for the larger demand.

316. Reliability estimation of public bus routes: Applicability of multivariate adaptive regression splines approach

1. Ozuysal, Mustafa; Caliskanelli, S. Pelin
2. CANADIAN JOURNAL OF CIVIL ENGINEERING

The performance of public bus lines is generally evaluated by comparing demand and ridership. However, reliability gain or loss by a proposed bus route should also be considered in the decision-making process to ensure a service that is preferable for users and operable for providers. In this study, it is aimed to provide a tool for predicting the reliability of a proposed bus route by considering route layout and traffic conditions. Travel time based reliability is predicted by using a novel nonparametric method, multivariate adaptive regression splines (MARS). Some critical thresholds of route layout parameters that should be considered for higher reliability are found. It is concluded that route lengths longer than 10 km, and number of intersections over 22 considerably decrease whole day based reliability. For peak hour based reliability, the types and numbers of intersections are found to be more efficient than the ones in whole day based model and a reliability regulator impact of roundabout numbers under nine is observed.

317. A Frequency-Based Assignment Model under Day-to-Day Information Evolution of Oversaturated Conditions on a Feeder Bus Service

1. Zhang, Silin; Yuan, Zhenzhou; Cao, Zhichao
2. INFORMATION

Day-to-day information is increasingly being implemented in transit networks worldwide. Feeder bus service (FBS) plays a vital role in a public transit network by providing feeder access to hubs and rails. As a feeder service, a space-time path for frequent passengers is decided by its dynamic strategy procedure, in which a day-to-day information self-learning mechanism is identified and analyzed from our survey data. We formulate a frequency-based assignment model considering day-to-day evolution under oversaturated conditions, which takes into account the residual capacity of bus and the comfort feelings of sitting or standing. The core of our proposed model is to allocate the passengers on each segment belonging to their own paths according to multi-utilities transformed from the time values and parametric demands, such as frequency, bus capacity, seat comfort, and stop layout. The assignment method, albeit general, allows us to formulate an equivalent optimization problem in terms of interaction between the FBS' operation and frequent passengers' rational behaviors. Finally, a real application case is generated to test the ability of the modeling framework capturing the theoretical consequents, serving the passengers' dynamic externalities.

318. A double time-scale passenger assignment model for high-speed railway networks with continuum capacity approximation

1. Xu, Guangming; Liu, Wei; Wu, Runfa; Yang, Hai
2. TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW

This study models spatiotemporal passenger flow distribution for high-speed railway (HSR) networks with capacity constraints. The HSR travel demand involves two time-dimensions, i.e., the ticket booking

time and the desired departure time. Under the principle of first-booked-first-served, a passenger flow assignment model is formulated, where a later ticket booking time may result in less available travel options. A solution algorithm is then designed for solving the ticket-booking-time-dependent assignment model. The model is tested and illustrated with two numerical examples: a toy network example and a large-scale Chinese HSR network example.

319. Time-dependent transportation network design that considers health cost

1. Jiang, Y.; Szeto, W. Y.
2. TRANSPORTMETRICA A-TRANSPORT SCIENCE

This paper proposes a bi-level optimisation framework for time-dependent discrete road network design that considers health impacts. A general health cost function is proposed and captured in the framework. The function simultaneously considers the health impacts of road traffic emissions, noise, and accidents due to network expansion. To solve the problem, the artificial bee colony (ABC) algorithm is proposed to search the network design solutions of the upper-level problem, while the method of successive averages and the Frank-Wolfe algorithm are adopted to solve the lower-level time-dependent land-use transportation problem. A repairing procedure is proposed to remedy infeasible solutions. A numerical study is set up to illustrate the conflict between maximising consumer surplus and minimising the health cost. This paper also reveals a paradox phenomenon that with an increasing amount of emissions, the health cost decreases. Moreover, the existence of a health inequity between different residential zones is demonstrated. A modified Sioux Falls network is adopted to show the performance of the solution algorithm as well as the effectiveness of the proposed repairing procedure.

320. 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. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

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.

321. Itinerary choice and advance ticket booking for high-speed-railway network services

1. Xu, Guangming; Yang, Hai; Liu, Wei; Shi, Feng

2. TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES

This paper formulates and examines the passenger flow assignment (itinerary choice) problem in high-speed railway (HSR) systems with multiple-class users and multiple-class seats, given the train schedules and time-varying travel demand. In particular, we take into account advance booking cost of travelers in the itinerary choice problem. Rather than a direct approach to model advance booking cost with an explicit cost function, we consider advance booking cost endogenously, which is determined as a part of the passenger choice equilibrium. We show that this equilibrium problem can be formulated as a linear programming (LP) model based on a three-dimension network representation of time, space, and seat class. At the equilibrium solution, a set of Lagrange multipliers for the LP model are obtained, which are associated with the rigid in train passenger capacity constraints (limited numbers of seats). We found that the sum of the Lagrange multipliers along a path in the three-dimension network reflects the advance booking cost of tickets (due to advance/early booking to guarantee availability) perceived by the passengers. Numerical examples are presented to demonstrate and illustrate the proposed model for the passenger assignment problem.