The restricted stochastic user equilibrium with threshold model: Large-scale application and parameter testing

This paper presents the application and calibration of the recently proposed Restricted Stochastic User Equilibrium with Threshold model (RSUET) to a large-scale case-study. The RSUET model avoids the limitations of the well-known Stochastic User Equilibrium model (SUE) and the Deterministic User Equilibrium model (DUE), by combining the strengths of the Boundedly Rational User Equilibrium model and the Restricted Stochastic User Equilibrium model (RSUE). Thereby, the RSUET model reaches an equilibrated solution in which the flow is distributed according to Random Utility Theory among a consistently equilibrated set of paths which all are within a threshold relative to the cost on the cheapest path and which do not leave any attractive paths unused. Several variants of a generic RSUET solution algorithm are tested and calibrated on a large-scale case network with 18,708 arcs and about 20 million OD-pairs, and comparisons are performed with respect to a previously proposed RSUE model as well as an existing link-based mixed Multinomial Probit (MNP) SUE model. The results show that the RSUET has very attractive computation times for large-scale applications and demonstrate that the threshold addition to the RSUE model improves the behavioural realism, especially for high congestion cases. Also, fast and well-behaved convergence to equilibrated solutions among non-universal choice sets is observed across different congestion levels, choice model scale parameters, and algorithm step sizes. Clearly, the results highlight that the RSUET outperforms the MNP SUE in terms of convergence, calculation time and behavioural realism. The choice set composition is validated by using 16,618 observed route choices collected by GPS devices in the same network and observing their reproduction within the equilibrated choice sets generated by the RSUET model. Relevantly, the RSUET model is very successful in reproducing observed link.

General information
State: Published
Organisations: Department of Management Engineering, Transport DTU, Transport Modelling, University of Leeds, University of Queensland
Authors: Rasmussen, T. K. (Intern), Nielsen, O. A. (Intern), Watling, D. P. (Ekstern), Prato, C. G. (Ekstern)
Pages: 1-24
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: European Journal of Transport and Infrastructure Research
Volume: 17
Issue number: 1
Promoting cycling aims at reducing congestion and pollution as well as encouraging healthy and sustainable lifestyles but generally clashes with the perception of crash risk while riding a bicycle that is still the most significant disincentive to cycling. This study sheds light on the factors affecting the probability of cyclist-motorist collisions while accounting for heterogeneity and spatial correlation. The current study analyzed the factors contributing to increase crash risk while riding a bicycle by focusing on 5,349 cyclist-motorist collisions within 269 traffic zones in the Copenhagen Region. The model controlled for traffic exposure for bicycles and motorized transport modes, evaluated the effects of infrastructure and socioeconomic characteristics of the zones, and accounted for heterogeneity and spatial correlation across the zones. A Poisson-lognormal model with second-order conditional autoregressive (CAR) priors confirmed the existence of the safety in numbers phenomenon, contradicted previous literature about bicycle facilities not being helpful in reducing crash risk, highlighted the need for Copenhagen-style bicycle paths especially in suburban areas, and emphasized how heterogeneity and spatial correlation play a significant role in explaining the probability of cyclist-motorist crash occurrence.

Infrastructure and spatial effects on the frequency of cyclist-motorist collisions in the Copenhagen Region
Promoting cycling aims at reducing congestion and pollution as well as encouraging healthy and sustainable lifestyles but generally clashes with the perception of crash risk while riding a bicycle that is still the most significant disincentive to cycling. This study sheds light on the factors affecting the probability of cyclist-motorist collisions while accounting for heterogeneity and spatial correlation. The current study analyzed the factors contributing to increase crash risk while riding a bicycle by focusing on 5,349 cyclist-motorist collisions within 269 traffic zones in the Copenhagen Region. The model controlled for traffic exposure for bicycles and motorized transport modes, evaluated the effects of infrastructure and socioeconomic characteristics of the zones, and accounted for heterogeneity and spatial correlation across the zones. A Poisson-lognormal model with second-order conditional autoregressive (CAR) priors confirmed the existence of the safety in numbers phenomenon, contradicted previous literature about bicycle facilities not being helpful in reducing crash risk, highlighted the need for Copenhagen-style bicycle paths especially in suburban areas, and emphasized how heterogeneity and spatial correlation play a significant role in explaining the probability of cyclist-motorist crash occurrence.

General information
State: Published
Organisations: Department of Transport, Traffic modelling and planning, Department of Management Engineering, Transport DTU, Danish National Police
Authors: Prato, C. G. (Intern), Kaplan, S. (Intern), Rasmussen, T. K. (Intern), Hels, T. (Ekstern)
Number of pages: 15
Pages: 346-360
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Transportation Safety & Security
Timetable-based simulation method for choice set generation in large-scale public transport networks

The composition and size of the choice sets are a key for the correct estimation of and prediction by route choice models. While existing literature has posed a great deal of attention towards the generation of path choice sets for private transport problems, the same does not apply to public transport problems. This study proposes a timetable-based simulation method for generating path choice sets in a multimodal public transport network. Moreover, this study illustrates the feasibility of its implementation by applying the method to reproduce 5131 real-life trips in the Greater Copenhagen Area and to assess the choice set quality in a complex multimodal transport network. Results illustrate the applicability of the algorithm and the relevance of the utility specification chosen for the reproduction of real-life path choices. Moreover, results show that the level of stochasticity used in choice set generation should be high in order to provide stable parameter estimates when the choice sets are used for estimation regardless of the initial parameters for choice set generation. Last, results illustrate that adding heterogeneity across travellers should be required because coverage increases significantly, a relevant result considering that models are becoming more disaggregate in nature in real-life applications.

General information
State: Published
Organisations: Traffic modelling and planning, Department of Management Engineering, University of Queensland
Authors: Rasmussen, T. K. (Intern), Anderson, M. K. (Intern), Nielsen, O. A. (Intern), Prato, C. G. (Ekstern)
Number of pages: 23
Pages: 467-489
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: European Journal of Transport and Infrastructure Research
Volume: 16
Issue number: 3
ISSN (Print): 1567-7141
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.536 SNIP 0.662 CiteScore 1.13
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.493 SNIP 0.791 CiteScore 1.17
Improved methods to deduct trip legs and mode from travel surveys using wearable GPS devices: A case study from the Greater Copenhagen area

GPS data collection has become an important means of investigating travel behaviour. This is because such data ideally provide far more detailed information on route choice and travel patterns over a longer time period than possible from traditional travel survey methods. Wearing a GPS unit is furthermore less requiring for the respondents than filling out (large) questionnaires. It places however high requirements to the post-processing of the data. This study developed and tested a combined fuzzy logic and GIS-based algorithm to process raw GPS data. The algorithm is applied to GPS data collected in the highly complex large-scale multi-modal transport network of the Greater Copenhagen area. It detects trips, trip legs and distinguishes between five modes of transport. The algorithm was validated by comparing with a control questionnaire collected among the same persons and a sensitivity analysis was performed. This showed that the algorithm (i) identified corresponding trip legs for 82% of the reported trip legs, (ii) avoided classifying non-trips such as scatter around activities as trip legs, (iii) identified the correct mode of transport for more than 90% of trip legs, and (iv) were robust towards the specification of the model parameters and thresholds. The method thus makes it possible to use GPS for travel surveys in large-scale multi-modal networks.

General information
State: Published
Organisations: Department of Transport, Traffic modelling and planning
Authors: Rasmussen, T. K. (Intern), Ingvardson, J. B. (Intern), Halldórsdóttir, K. (Intern), Nielsen, O. A. (Intern)
Pages: 301–313
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Computers, Environment and Urban Systems
Volume: 54
ISSN (Print): 0198-9715
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 1.14 SNIP 1.939 CiteScore 3.39
BFI (2015): BFI-level 1
Stochastic user equilibrium with equilibrated choice sets: Part II - Solving the restricted SUE for the logit family

We propose a new class of path-based solution algorithms to solve the Restricted Stochastic User Equilibrium (RSUE), as introduced in Watling et al. (2015). The class allows a flexible specification of how the choice sets are systematically grown by considering congestion effects and how the flows are allocated among routes. The specification allows adapting traditional path-based stochastic user equilibrium flow allocation methods (originally designed for pre-specified choice sets) to the generic solution algorithm. We also propose a cost transformation function and show that by using this we can, for certain Logit-type choice models, modify existing path-based Deterministic User Equilibrium solution methods to compute RSUE solutions. The transformation function also leads to a two-part relative gap measure for consistently monitoring convergence to a RSUE solution. Numerical tests are reported on two real-life cases, in which we explore convergence patterns and choice set composition and size, for alternative specifications of the RSUE model and solution algorithm.

General information
State: Published
Organisations: Department of Transport, Traffic modelling and planning, University of Leeds
Authors: Rasmussen, T. K. (Intern), Watling, D. P. (Ekstern), Prato, C. G. (Intern), Nielsen, O. A. (Intern)
Number of pages: 20
Pages: 146-165
The aim of this paper is to remove the known limitations of Deterministic and Stochastic User Equilibrium (DUE and SUE), namely that only routes with the minimum cost are used in DUE, and that all permitted routes are used in SUE regardless of their costs. We achieve this by combining the advantages of the two principles, namely the definition of unused routes in DUE and of mis-perception in SUE, such that the resulting choice sets of used routes are equilibrated. Two model families are formulated to address this issue: the first is a general version of SUE permitting bounded and discrete error distributions; the second is a Restricted SUE model with an additional constraint that must be satisfied for unused paths. The overall advantage of these model families consists in their ability to combine the unused routes with the use of random utility models for used routes, without the need to pre-specify the choice set. We present model specifications within these families, show illustrative examples, evaluate their relative merits, and identify key directions for further research.
Traffic assignment models in large-scale applications

Transport models are becoming more and more disaggregate to facilitate a realistic representation of individuals and their travel patterns. In line with this development, the PhD study focuses on facilitating the deployment of traffic assignment models in fully disaggregate activity-based model frameworks. In the correct integration, such frameworks allow realistic representation of individual-specific household interactions, time-space constraints and preference structures. Individual trips can also be evaluated on a detailed address-to-address level and aggregation biases are avoided. The study focuses on large-scale applications and contributes with methods to actualise the true potential of disaggregate models. To achieve this target, contributions are given to several components of traffic assignment modelling, by (i) enabling the utilisation of the increasingly available data sources on individual behaviour in the model specification, (ii) proposing a method to use disaggregate Revealed Preference (RP) data to estimate utility functions and provide evidence on the value of congestion and the value of reliability, (iii) providing a method to account for individual mis-perceptions in the choice set generation for complex multi-modal networks, and (iv) addressing the difficulty of choice set generation by making available a theoretical framework, and corresponding operational solution methods, which consistently distinguishes between used and unused paths. The availability of data is essential in the development and validation of realistic models for large-scale applications. Nowadays, modern technology facilitates easy access to RP data and allows large-scale surveys. The resulting datasets are, however, usually very large and hence data processing is necessary to extract the pieces of information relevant to the analysis at hand. Manual processing of the datasets is typically not possible, and it is therefore necessary to have methods available which in some automated ways clean and prepare the datasets for the desired use. The present study proposes a fully automatic post-processing procedure that combines fuzzy logic- and GIS-based methods to process raw individual-based GPS data with no additional information required from the respondent. The method categorises trips and trip legs and associates the trip legs with the most probable mode of transport used. The method was validated through the application to a dataset consisting of raw individual-based GPS logs collected among 183 respondents living in the Greater Copenhagen area. Through the use of a control-questionnaire, the study found that the proposed method (i) vi identified corresponding trip legs for 82% of the reported trip legs, (ii) avoided classifying nontrips such as scatter around activities as trip legs, and (iii) identified the correct mode of transport for more than 90% of the trip legs. These results are very promising, especially when compared to results generated by existing algorithms. The results highlight the potential of the method proposed and the possibility to use individual-based GPS units for travel surveys in real-life large-scale multi-modal networks. Congestion is known to highly influence the way we act in the transportation network (and organise our lives), because of longer travel times, but the reliability of the travel time also has a large impact on our travel choices. Consequently, in order to improve the realism of transport models, correct understanding and representation of two values that are related to the value of time (VoT) are essential: (i) the value of congestion (VoC), as the VoT varies with traffic conditions and hence congestion multipliers reflect the complexity of driving conditions when more vehicles are present on the road, and (ii) the value of reliability (VoR), as the VoT relates to the predictability of travel time and the repeatability of the travel experience. Congestion and reliability highly influence each other, but so far only studies based on Stated Preference (SP) data considered concurrently congestion and reliability variables. The PhD study contributes to the state-of-the-art by presenting a new approach to estimate the VoR and VoC based on RP data. The approach applies a mean-variance model that considers congestion and reliability concurrently. The model was applied to GPS data and it successfully estimated mixed Path Size Logit models, using a sample of 5,759 observations in the peak period and a sample of 7,964 observations in the off-peak period. Results
illustrated that the value of the different time components (free-flow, congestion, and reliability) and the congestion multiplier were significantly higher in the peak period. This seems reasonable because of possible higher penalties for being late and, as a consequence, possible higher time pressure. Results also showed that the marginal rate of substitution between travel time reliability and the total travel time, considering the average congestion level, did not vary across time periods and traffic conditions. The study highlights the potential of exploiting the growing availability of observations of actual behaviour to obtain estimates of the (monetary) value of different travel time components, thereby increasing the behavioural realism of largescale models. vii The generation of choice sets is a vital component in route choice models. This is, however, not a straight-forward task in real-life applications, as: (i) there are almost infinitely many alternatives, but large choice sets are computationally demanding or even unfeasible; (ii) congestion effects need to be considered; (iii) the choice sets should contain all relevant alternatives, including the observed route if one such is available, while leaving out nonreasonable and redundant routes; and (iv) the attributes of the alternatives should vary enough to facilitate consistent parameter estimates if the choice sets are to be used for choice model estimation. The PhD study contributes to the state-of-the-art by proposing and validating a simulation-based choice set generation method for general networks. The validation used 5,131 observed route choices collected on the highly complex large-scale Greater Copenhagen area public transport network. By evaluating alternative ways to specify the stochasticity and the level of this, it was found that the level of stochasticity should be high to induce high coverage and statistically efficient parameter estimates when the choice sets are used for estimation. The level of stochasticity should, however, be introduced with parsimony, as significant increases translate into generating redundant and counter-intuitive paths with no considerable improvement in coverage. Adding heterogeneity across travellers improved the results considerably, and induced coverage levels up to a very high 98.8% at an 80% overlap threshold. This shows the potential of the method proposed as well as the importance of accounting for as much individual heterogeneity as possible as models become more disaggregate. A revisit to the original conditions underlying the Stochastic User Equilibrium (SUE) has led to the realisation that the difficulty of specifying the choice set is related to the assumption on the distribution of the mis-perceptions. It is the commonly adopted assumption that the distributed elements follow unbounded distributions which induces the need to enumerate all paths in the SUE, no matter how unattractive they might be. The Deterministic User Equilibrium (DUE), on the other hand, has a built-in criterion distinguishing definitely unused from potentially used routes, but the cut-off in terms of cost differences is strict. Based on this, two new model frameworks and corresponding equilibrium formulations are introduced. Both models combine the strengths of the SUE and DUE by permitting the consistent combination viii of (i) equilibrated non-universal choice sets and (ii) flow distribution according to random utility maximisation theory. One model allows distinction between used and unused routes based on the distribution of the random error terms, while the other model allows this distinction by posing restrictions on the costs of used/unused routes. Generic path-based solution algorithms and convergence measures are introduced for the model which seemed the most straightforward to apply given its connection to existing RUMbased models (the one adding restrictions). Different variants of the algorithms were validated for the MultiNomial Logit and Path Size Logit choice models on the Sioux Falls as well as the large-scale Zealand network. A novel consistent convergence measure verified extremely fast and well-behaved convergence to an equilibrated solution on non-universal choice sets (across different congestion levels, scale parameters and step-sizes). The composition of the choice sets were validated by comparison to real-life route choices of 16,618 individual trips on the Zealand network. The applications were also very successful in reproducing observed link counts. The solution algorithms are thus computationally attractive, and the solutions and the underlying framework are behaviourally realistic. This causes the new framework and solution algorithms to be highly attractive to apply as models become more disaggregate. Summarising, the PhD study has given contributions to several of the components that concern the estimation and solution of traffic assignment models in large-scale applications. Through this, the PhD study has successfully facilitated the consistent integration at the disaggregate level across traffic model parts. This means that the true potential of the activity-based models can be actualised.

General information
State: Published
Organisations: Department of Transport, Traffic modelling and planning, Rapidis Aps
Authors: Rasmussen, T. K. (Intern), Nielsen, O. A. (Intern), Prato, C. G. (Intern), Frederiksen, R. D. (Ekstern)
Number of pages: 345
Publication date: 2015

Publication information
Publisher: Technical University of Denmark, Transport
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
PhD_Thesis_ThomasKRasmussen_print.pdf
Publication: Research › Ph.D. thesis – Annual report year: 2015

Estimating Value of Congestion and of Reliability from Observation of Route Choice Behavior of Car Drivers
In recent years, a consensus has been reached about the relevance of calculating the value of congestion and the value of reliability for better understanding and therefore better prediction of travel behavior. The current study proposed a revealed preference approach that used a large amount of GPS data from probe vehicles to provide insight into actual behavior in choosing a route. Mixed path size correction logit models were estimated from samples of 5,759 observations in the peak period and 7,964 observations in the off-peak period, while a mean-variance model was specified to consider
both congestion and reliability terms. Results illustrated that the value of time and the value of congestion were significantly higher in the peak period because of possible higher penalties for drivers being late and consequently possible higher time pressure. Moreover, results showed that the marginal rate of substitution between travel time reliability and total travel time did not vary across periods and traffic conditions, with the obvious caveat that the absolute values were significantly higher for the peak period. Last, results showed the immense potential of exploiting the growing availability of large amounts of data from cheap and enhanced technology to obtain estimates of the monetary value of different travel time components from the observation of actual behavior, with arguably potential significant impact on the realism of large-scale models.

**General information**

- **State:** Published
- **Organisations:** Department of Transport, Traffic modelling and planning, Technical University of Denmark
- **Authors:** Prato, C. G. (Intern), Rasmussen, T. K. (Intern), Nielsen, O. A. (Intern)
- **Number of pages:** 8
- **Pages:** 20-27
- **Publication date:** 2014
- **Main Research Area:** Technical/natural sciences

**Publication information**

- **Journal:** Transportation Research Record
- **Volume:** 2412
- **Issue number:** 2412
- **ISSN (Print):** 0361-1981
- **Ratings:**
  - BFI (2017): BFI-level 1
  - Web of Science (2017): Indexed Yes
  - BFI (2016): BFI-level 1
  - Scopus rating (2016): SJR 0.494 SNIP 0.722 CiteScore 0.75
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 1
  - Scopus rating (2015): SJR 0.547 SNIP 0.769 CiteScore 0.6
  - Web of Science (2015): Indexed yes
  - BFI (2014): BFI-level 1
  - Scopus rating (2014): SJR 0.529 SNIP 0.8 CiteScore 0.58
  - Web of Science (2014): Indexed yes
  - BFI (2013): BFI-level 1
  - Scopus rating (2013): SJR 0.608 SNIP 0.877 CiteScore 0.76
  - ISI indexed (2013): ISI indexed yes
  - Web of Science (2013): Indexed yes
  - BFI (2012): BFI-level 1
  - Scopus rating (2012): SJR 0.522 SNIP 0.907 CiteScore 0.6
  - ISI indexed (2012): ISI indexed yes
  - Web of Science (2012): Indexed yes
  - BFI (2011): BFI-level 1
  - Scopus rating (2011): SJR 0.428 SNIP 0.999 CiteScore 0.72
  - ISI indexed (2011): ISI indexed yes
  - Web of Science (2011): Indexed yes
  - BFI (2010): BFI-level 1
  - Scopus rating (2010): SJR 0.398 SNIP 0.959
  - Web of Science (2010): Indexed yes
  - BFI (2009): BFI-level 1
  - Scopus rating (2009): SJR 0.393 SNIP 0.79
  - Web of Science (2009): Indexed yes
  - BFI (2008): BFI-level 1
  - Scopus rating (2008): SJR 0.392 SNIP 0.747
  - Web of Science (2008): Indexed yes
  - Scopus rating (2007): SJR 0.377 SNIP 0.728
  - Web of Science (2007): Indexed yes
Risk Factors Associated with Crash Severity on Low-Volume Rural Roads in Denmark

Safety on low-volume rural roads is drawing attention due to the high fatality and severe injury rates in comparison with high-volume roads and the increasing awareness of sustainable rural development among policy makers. This study analyzes the risk factors associated with crash severity on low-volume rural roads, including crash characteristics, driver attributes and behavior, vehicle type, road features, environmental conditions, distance from the nearest hospital, and zone rurality degree. The data consist of a set of crashes occurred on low-volume rural roads in Denmark between 2007 and 2011. The crashes were identified by map-matching the crash location to the geographic information system representing the national transport network and extracting the relevant crashes based on annual average traffic volumes. Injury severity was modeled by estimating a generalized ordered logit model due to its advantage in accommodating the ordered-response nature of severity while relaxing the proportional odds assumption. Model estimates and pseudoelasticities show that aggravated crash injury severity is significantly associated with (1) alcohol and failure to wear seatbelts, (2) involvement of vulnerable road users (i.e., pedestrians, cyclists and motorcyclists), (3) involvement of heavy vehicles, (4) speed limits of 80–90 km/h, (5) longer distance to the nearest hospital, and (6) peripheral rural regions.

General information

State: Published
Organisations: Department of Transport, Traffic modelling and planning
Authors: Prato, C. G. (Intern), Rasmussen, T. K. (Intern), Kaplan, S. (Intern)
Pages: 1-20
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information

Journal: Journal of Transportation Safety & Security
Volume: 6
Issue number: 1
ISSN (Print): 1943-9962
Ratings:
Web of Science (2017): Indexed Yes
Scopus rating (2016): SJR 0.476 SNIP 0.613 CiteScore 0.69
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 0.351 SNIP 0.497 CiteScore 0.46
Scopus rating (2014): SJR 0.328 SNIP 0.558 CiteScore 0.46
Scopus rating (2013): SJR 0.618 SNIP 1.036 CiteScore 0.86
ISI indexed (2013): ISI indexed no
Scopus rating (2012): SJR 0.29 SNIP 0.641 CiteScore 0.42
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.111 SNIP 0.326 CiteScore 0.23
ISI indexed (2011): ISI indexed no
A disaggregate pseudo-dynamic assignment for the activity-based model of the Greater Copenhagen Area

The COMPAS (Copenhagen Model for Person Activity Scheduling) model being developed for the Greater Copenhagen Area recognizes the limitations of traditional approaches to transport planning, and embraces the active stream of research focusing on the activity-based paradigm for predicting travel demand and supply. On the demand side, the COMPAS model proposes a micro-simulation approach to the representation of activity and travel patterns of Copenhageners as individuals and household members. On the supply side, the COMPAS model proposes a disaggregate pseudo-dynamic approach to the assignment of Copenhageners to the multimodal network of the Greater Copenhagen Area. This paper focuses on the development of the framework for the supply side of the COMPAS model. The framework is developed by considering that using an activity-based paradigm with a static traffic assignment negates much of the advantages of predicting travel patterns at the disaggregate level in continuous time. Accordingly, the proposed traffic assignment is individual-based, pseudo-dynamic, and multi-modal. Firstly, the assignment loads onto the network activity and travel patterns of the individuals between parcels. Secondly, the framework uses a pseudo-dynamic approach able to capture the dynamic nature of the travel pattern of the individuals and hence the building of congestion. Last, the framework loads onto the network car users, public transport users and the important share of cyclists commuting in the Greater Copenhagen Area.

The framework proposes interesting insights from a behavioral and a time perspective. From a behavioral perspective, the framework allows representing individual preference structures depending on individual attributes (e.g., value-of-time, income, age) and incorporating non-linear terms in the utility functions. The calculation of level-of-service for non-chosen alternatives (e.g., non-chosen routes, non-chosen modes, non-chosen destinations) may be solved with ghost probes running (but not loading) the network. From a time perspective, the proposed framework has a complexity similar to the static assignment. While adding the time dimension to a matrix-based assignment increases the calculation complexity significantly, proposing an individual-based approach requires only some more updating of speed-flow and flow-density functions is required. The advantages are the complexity similar to static assignment, the absence of loss of information on the trips from the demand model, the increase in explanation and prediction abilities, and the avoidance of aggregation bias of the level-of-service variables in the feedback to the demand models. The disaggregate pseudo-dynamic traffic assignment allows: (i) capturing time-dependent interactions of travel demand and network supply of the network; (ii) representing the network at a disaggregate level; (iii) representing congestion build-up and dissipation; (iv) evaluating the effect of traffic management measures and traffic policies. When considering the main policies discussed in the Greater Copenhagen Area (e.g., measures of traffic control management, adoption of intelligent transport systems, adoption of road pricing policies), a state-of-the-art instrument such as an activity-based model with an individual-based pseudo-dynamic traffic assignment will prove highly valuable to decision makers.

Issues in current User Equilibrium models and introduction of the Restricted Stochastic User Equilibrium conditions

Deterministic User Equilibrium (DUE) models are attractive for realistic-scale transportation networks as they do not require a pre-specification of ‘relevant routes’, but implicitly allow some routes to be used for a given trip, while leaving many unattractive routes unused. However, the cut-off is strictly enforced: in a time-only model, if the current equilibrium travel time is 15.3 minutes, then adding a route with travel time of 15.4 minutes will have no impact on routing behaviour, whereas in practice (because of uncertainty, variability and unobserved attributes) the new route is likely to be attractive to some travellers. Stochastic User Equilibrium (SUE) models allow sort of ‘smoothing’ this condition, in that routes with higher travel time will be less used. This means that, with a customary specification with a continuous random error term with infinite support, SUE models will assign some flow to all feasible routes. If the set of feasible routes is assumed to be all acyclic routes, then this could be said to be implausible for a different reason to the DUE case: adding any route of any length will have some impact on SUE routing, even if entirely nonsensical for the trip being made. This issue is further complicated by the fact that typically only a sub-set of possible routes will be identified in numerical algorithms solving for SUE.

In the current study, we present new alternative forms of SUE conditions that permit unused alternatives, accommodate behaviour on used alternatives according to Random Utility Theory, and are generic in the sense that may be applied to any SUE model and any solution method. We define this new set of conditions as the Restricted Stochastic User
Equilibrium (RSUE) conditions. Then, we focus on solution algorithms and we argue that many SUE solution algorithms are computationally expensive by requiring simulation. Additionally, identifying all possible routes for realistic-scale networks quickly gets intractable, and most algorithms require pre-specification of 'relevant routes', which can be a difficult task. Recognizing the limitations of solution algorithms to the behaviourally sound SUE and the efficiency of solution algorithms to the DUE, we introduce a transformation of the cost function. This transformation function opens up a larger array of possible solution algorithms to the SUE, as it allows us to apply any path-based DUE solution algorithm and then obtain a flow solution which satisfies the RSUE or SUE on a pre-specified choice set. The underlying choice model is however restricted to being logit-type. Due to the consistency with the IIA property of logit-type models, we propose heuristic solution algorithms where the direction finding is based on a pair-wise path-swapping algorithm. The transformation function also leads to the proposal of a new Relative GAP-measure (convergence measure) valid for any SUE or RSUE solution algorithm based on the logit-type choice models. Numerical tests on a synthetic network as well as the Sioux Falls network indicate that the proposed solution algorithms induce interesting and promising convergence patterns.

Risk factors associated with crash severity on low-volume rural roads in Denmark
Safety on low-volume rural roads is drawing attention due to the high fatality and severe injury rates in comparison with high-volume roads and the increasing awareness of sustainable rural development among policy makers. This study analyzes the risk factors associated with crash severity on low-volume rural roads, including crash characteristics, driver attributes and behavior, vehicle type, road features, environmental conditions, distance from the nearest hospital, and zone rurality degree. The data consist of a set of crashes occurred on low-volume rural roads in Denmark between 2007 and 2011. The crashes were identified by map-matching the crash location to the geographic information system representing the national transport network and extracting the relevant crashes based on annual average traffic volumes. Injury severity was modeled by estimating a generalized ordered logit model due to its advantage in accommodating the ordered-response nature of severity while relaxing the proportional odds assumption. Model estimates and pseudo-elasticities show that aggravated crash injury severity is significantly associated with (i) alcohol and failure to wear seatbelts, (ii) involvement of vulnerable road users (i.e., pedestrians, cyclists and motorcyclists), (iii) involvement of heavy vehicles, (iv) speed limits of 80-90 km/h, (v) longer distance to the nearest hospital, and (vi) peripheral rural regions.
Projects:

**Mesoscopic Simulation of Multi-Model Urban Traffic**

Department of Management Engineering  
Period: 01/07/2017 → 30/06/2020  
Number of participants: 3  
Phd Student:  
Paulsen, Mads (Intern)  
Supervisor:  
Rasmussen, Thomas Kjær (Intern)  
Main Supervisor:  
Nielsen, Otto Anker (Intern)

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Samfinansieret - Andet  
Project: PhD

**Disaggregate activity-based traffic assignment modelling**

Department of Transport  
Period: 01/05/2011 → 23/02/2015  
Number of participants: 7  
Phd Student:  
Rasmussen, Thomas Kjær (Intern)  
Supervisor:  
Frederiksen, Rasmus Dyhr (Intern)  
Prato, Carlo Giacomo (Intern)  
Main Supervisor:  
Nielsen, Otto Anker (Intern)  
Examiner:  
Larsen, Allan (Intern)  
Bekhar, Shlomo (Ekstern)  
Cantarella, Giulio Erberto (Ekstern)

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU) Samf.  
Project: PhD