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.

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