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Continuous Optimization

A rank-dependent bi-criterion equilibrium model for stochastic transportation environment

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A R T I C L E I N F O

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A B S T R A C T

The paper proposes a rank-dependent bi-criterion (travel time & monetary travel cost) equilibrium model for route choice problems, stochasticities in both the criteria measurements and the subjective preferences are considered simultaneously. Travelers rank all the choices, according to the generalized travel dis-utility, then choose from the first several (see K) best ranked ones. By searching inversely the supporting preference sets for each alternative in each rank, the overall choice probability of a path is determined. The equilibrium model is formulated and transformed into a fixed-point problem. The existence of the equilibrium is given out for a simple two-link network, however may not be guaranteed for more complex network topologies. When $K = 1$, the proposed model reduces to the optimal user equilibrium that allows for the stochasticities of criteria measurements and the arbitrarily distributed preferences. Some remarks about the selection of some parameters in the new model are discussed and also the solution algorithms. Two numerical examples are presented to illustrate the implementation of the model, and also the capability and flexibility of the new model in handling the heterogeneity in traveler preferences and requirements. The paper concludes with discussions about the assumptions and limitations of the new model and possible future research opportunities as well.

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1. Introduction

Multi-criteria traffic equilibrium models explicitly consider that travelers base their choice decisions on multi-criteria, such as travel time, monetary travel cost, accessibility and stability, parking availability as well as destination attractiveness and so on. Travelers evaluate the choice alternatives referring to these criteria according to personal preferences (priority or weight distribution across the criteria), and choose one that minimize (maximize) the general trip disutility (utility), or one satisfiable. Multi-criteria based transportation researches cover many aspects, including the GIS-based multicriteria route/tour plan support (Nadi & Delavar, 2011; Niaraki & Kim, 2009; Niaraki, Kim, & Varshosaz, 2010), (vehicle) routing (Blue, Adler, & List, 1998; Bowerman, Hall, & Calamai, 1995; Doerner, Focke, & Gutjahr, 2007; Jozefowiez, Semet, & El-Ghazali, 2008; Raith, 2009; Tan, Chew, & Lee, 2006b; Tan, Chew, & Lee, 2006a) or evacuation routing (Stepanov & Smith, 2009); and the network equilibrium modeling (Chen, Oh, Park, & Recker, 2010; Dafermos, 1982; Dial, 1979; Leurent, 1993; Raith, Wang, Ehrgott, & Mitchell, 2013; Wang & Ehrgott, 2013), which is also the concern of this paper.

In the researches associated with network equilibrium modeling, travel time and monetary travel cost based bi-criterion researches are widely investigated (Jiang, Mahmassani, & Zhang, 2011; Lu, Mahmassani, & Zhou, 2008; Mahmassani, Zhou, & Lu, 2005; Wang, Ehrgott, & Chen, 2013). Travelers perceive all the route alternatives by combining the two criteria with subjective value of time (VOT) beliefs, i.e., the relative magnitude of travel time to monetary cost, or the money units one willing to pay to save a time unit, and then choose from the optimal ones. The bi-criterion equilibrium models play an important role in many choice associated estimations, f.i., route choice equilibrium (assignment) models (Dial, 1996; Dial, 1997; Huang & Li, 2007; Leurent, 1996; Nagurney, 2000; Nagurney & Dong, 2002a) congestion pricing (Chen & Yang, 2012; Dial, 1999a; Dial, 1999b; Guo, 2013; Guo & Yang, 2009; Han & Yang, 2008; Jiang et al., 2011; Yang & Huang, 2004; Zhang, Yang, & Huang, 2008), and some other researches related to landuse and site selection (Briggs, Kunsch, & Mareschal, 1990; Jankowski et al., 1994; Rinner & Matin, 2004).

Generally, the building-up of a bi-criterion network equilibrium model may concern many factors, including path choice type (probabilistic or deterministic path choice decision), travel demand type (fixed or elastic demand), model dynamics (static or dynamic), the VOT belief pattern (fixed, continuous or discrete distributed, class specified or purpose specified and alike), the var-

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iation and flow dependence of each criterion measurement, extra information (ATIS available or not), the formation of the model (Optimization, inf.- and fin.-dimentional VI, and Nonlinear complementarity problem (NCP)) and so on. Table 1 gives a selective summary of some related research works mainly cover the concerns mentioned above. There are also some researches considering more than two criteria, see e.g., Nagurney, Dong, and Mokhtarian (2002b) and Jaber and O'mahony (2009), however not covered in this paper. The extension of the bi-criterion model to a more-than-two criteria one is direct but more complicated in computation.

Most of above studies consider only the best choices or assume that travelers always try to maximize (minimize) personal travel (dis-) utility, while those inferior composite alternatives, though may satisfy DMs' requirements, are not included. However, since travelers may differ in experiences of travel time as well as travel cost, and may differ in their VOT holdings which are hard to recognize clearly, it is impossible and unnecessary for them to evaluate and compare all the route alternatives based on precise computations of the overall disutilities. Especially for daily 'trial' decision occasions, a 'good' and satisfiable choice is enough to meet one's requirement. Thus, the conventional cardinal value based behavioral assumption may not suit well, when considering the stochastic multiple criteria measurements and the vague and heterogenous individual preferences, a simple while intuitive individual decision mechanism is needed. To this end, this paper proposes a rank-dependent user equilibrium (RDUE) model initiated from the concept of Stochastic Multi-criteria Acceptability Analysis (SMAA, Lahdelma, Joonas, & Salminen, 1998). SMAA is a class of Multi-Criteria Decision Aiding (MCDA) methods for discrete issues. By exploring the VOT preference space, SMAA calculates the (rank) acceptability indices measuring the variety of VOTs supporting each choice with certain rank, in other words, the probability of an alternative being preferred in that rank. SMAA deals with uncertain criteria measurements representing as probability distributions, and imprecise, partial or ignorance of preference information. It is capa-

Table 1
Some selective Bi-Criterion (time & cost) traffic network equilibrium contributions post-1990.

Citation	Flow dependence	Type of demand	Stochasticity of measurements	VOT pattern	Formulation	Qualitative properties
Leurent (1993)	Time only; separable functions	Elastic; separable not class-dependent	No		Optimization	Existence uniqueness
Marcotte et al. (1996), see also Marcotte and Zhu (1994)	Yes, general functions	Fixed; class-dependent	Cost only	Continuously distributed	inf.-dim.VI	Yes
Leurent (1996)	Time only; general functions	Elastic; not class-dependent	No	Continuously distributed	fin.-dim.VI	Existence; uniqueness
Dial (1996) Dial (1997)	Yes, separable functions	Fixed; class-dependent	No	Continuously distributed	Optimization; inf.-and fin.-dim.VI	Yes
Marcotte (1998)	Yes,general functions	Fixed; class-dependent	No	Continuously distributed	inf.-dim.VI fin.-dim.VI	Existence
Dial (1999a) Dial (1999b)	Yes,separable functions	Fixed; class-dependent	No	Continuously distributed	Optimization; inf.-and fin.-dim-VI	Yes
Nagurney (2000)	Yes,general functions	Fixed; class-dependent	No	Discrete class-dependent	fin.-dim.VI	Existence; uniqueness in special cases
Nagurney and Dong (2002a)	Yes,general functions	Elastic; class-dependent	No	Class-dependent; link-dependent	fin.-dim.VI	Yes
Yang and Huang (2004)	Time only; separable functions;	Fixed; class-dependent	No	Discrete; class-dependent	Optimization	Existence; uniqueness
Huang and Li (2007)	Yes,separable functions	Fixed; class-dependent	Yes	Discrete; class-dependent	Fixed-point problem	Existence
Han and Yang (2008)	Time only;	Fixed; class-dependent	No	Discrete; class-dependent	fin.-dim VI	Existence; Non-Unique
Clark et al. (2009)	Time only; separable functions	Elastic; class-dependent	No	Discrete; class-dependent	Optimization fin.-dim.VI	Yes; uniqueness in special cases
Guo and Yang (2009)	Time only	Fixed	No	Discrete class-dependent	Optimization	Existence uniqueness in special cases
Chen et al. (2010)	Time only general functions	Variable; endogenously generated	No	–	NCP	Yes (Equivalent to UE model)
Wang et al. (2013)	Time only separable functions	Fixed	No	Class-specified	Optimization NCP	Existence
Zhang et al. (2013)	Time only	Time varying OD demand	Yes	Continuously distributed	inf.-dim VI Fixed point problem	Existence

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