Guest Editorial: Special Issue on Quantitative Approaches to Environmental Sustainability in Transportation Networks

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Environmental sustainability is closely related to transportation, especially road networks, because vehicle emissions and noise damage the environment and have adverse effects on human health (Szeto et al., 2012). Vehicle emissions include greenhouse gases, which contribute to climate change. It is thus important to quantify and account for their effects when designing, planning, managing, and controlling transportation networks. Environmental sustainability is a hot topic, and much effort has been put into developing quantitative approaches and transportation network models to address the environmental sustainability issues related to transportation (e.g., Moura et al., 2010; Daziano and Bolduc, 2013; Ng and Lo, 2013; Zhu et al., 2013; Li et al., 2014; Long et al., 2014, 2015; Miandoabchi et al., 2015; Szeto et al., 2014, 2015; Jiang and Szeto, 2015). This special issue includes 18 articles and focuses on the recent advances in quantitative approaches to environmental sustainability in transportation networks. The topics covered can be categorized as follows:

- The first four articles focus on approaches to facilitating bicycle transportation planning and systems;
- The fifth to seventh articles focus on new modeling approaches for research problems associated with electric vehicles;
- The eighth to ninth articles focus on approaches to enhancing toll charging design;
- The tenth to fourteenth articles focus on approaches to achieving environmentally sustainable logistics systems;
- The fifteenth to seventeenth articles focus on novel modeling approaches for environmental impact assessment; and
- The final article focuses on a new modeling approach to aircraft trajectory optimization in a contrail-sensitive environment.

1. Bikeway network design model for recreational bicycling in scenic areas

Lin and Liao, develop a bikeway network design model for recreational bicycling in scenic areas. The model is designed to produce a bikeway network that can meet tourists' needs in terms of four objectives—maximizing bikeway service coverage, maximizing service station coverage, maximizing bikeway suitability, and minimizing cyclist risk—while avoiding negative effects on existing road users, residents, and environmentally sensitive areas. The model is formulated as a multi-objective 0-1 program, which is used to determine the spatial layout of a bikeway network. Constraints are placed on network connectivity, bikeway type, monetary budget, the desired relationship between bikeways and service stations, and value ranges of decision variables. The ε-constraint method is used to solve the program. The results of a case study undertaken in northern Taiwan indicate that the bikeway network found by the approach is superior to the existing bikeway network. The proposed model indeed provides a systematic and effective tool for planners involved in planning recreational bikeway networks.

2. Modeling mode and route similarities in network equilibrium problem with go-green modes

Kitthamkesorn et al. develop a new modal split assignment model using recent advances in discrete choice modeling methodology. Their model considers mode and route similarities in congested networks. The modal split problem is modeled by a nested logit (NL) model to account for the mode similarity among the available modes, while route overlapping in the traffic assignment problem is captured by a cross-nested logit (CNL) model. The results of numerical examples indicate that the proposed combined NL-CNL model has the potential to enhance the behavioral modeling of travelers' mode choice shift between private motorized travel, public transit, and bicycle travel, as well as their mode-specific route choices. This study

contributes to the literature by proposing a useful model for evaluating the effectiveness of various bicycle promotion strategies and for helping bikeway network planning.

3. Robust multi-period fleet allocation models for bike-sharing systems

Lu describes a robust multi-period fleet allocation and redistribution model for bike-sharing systems. Two robust models are developed by applying a robust optimization approach to address uncertain demand and optimize the performance of the bike-sharing system under worst-case demand scenarios. Using the North Taipei City public bike system as a case study, the results of the numerical examples indicate that the proposed models can obtain effective bike fleet allocations and redistribution plans over multiple periods. The robust model results show that the hedge value is larger than the robust cost, which indicates that the benefit of applying robust solutions in the worst-case scenario is larger than the price of employing the robust solution in the nominal demand scenario. This study fills the gap in the literature on the optimal fleet allocation problem for bike-sharing systems and provides a clear direction for future research on the topic. The proposed model and its results are useful for the planning, design, and management of bike-sharing systems.

4. Exploring heterogeneity in cycle tourists' preferences for an integrated bike-rail transport service

Chen and Cheng investigate the increasing popularity of cycling tourism and explore heterogeneity in cycle tourists' preferences for integrated bike-rail transport services using a case study from Taiwan. The stated preference approach and mixed logit models are used to examine cycle tourists' preferences regarding integrated bike-rail transport services. The results indicate that cycle tourists in general are concerned about the service attributes of integrated bike-rail transport services, such as price, type of bike storage, bike storage location, and service frequency. Chen and Cheng also find that different cycle tourist groups may differ in their willingness-to-pay and in their preferences for different service attributes. The study provides evidence that heterogeneous preferences exist among cycle tourists associated with the tourists' level of recreation specialization. Thus, it is useful in that it will allow integrated rail-bike transport service providers to improve their planning strategies and develop more effective marketing strategies to reach cycle tourist groups with different preferences.

5. Influence of social networks on latent choice of electric cars: A mixed logit specification using experimental design data

Rasouli and Timmermans undertake a systematic investigation of the relative effects of social networks on the latent choice of electric cars using a mixed logit model. They consider a wide set of attributes, including vehicle, contextual, and social network attributes. Two mixed logit models are developed: one allows for random effects from social influence attributes and the other allows for random effects from vehicle and contextual attributes. The results indicate that the two models are exceptionally different in terms of the shape of their utility curves. The model results indicate that the relative costs of electric cars and its attributes are vital in the choice of electric cars, while social network effects are relatively small. This study enriches the existing literature by extending the conventional choice experiments into the context of the influence of social networks on the acceptance of electric cars. The proposed models and their results are also useful for market share prediction.

6. Optimal prices of electricity at public charging stations for plug-in electric vehicles

He et al. develop a multi-class combined distribution and assignment model to optimize road tolls and the prices of electricity at public charging stations to minimize real power losses in the distribution grid and to reduce total travel time on the transportation network. The pricing model is formulated as a mathematical program with complementary constraints and solved by a manifold sub-optimization algorithm and a pattern search method. Power flow equations are adopted to estimate real power losses. The model results indicate that the pricing of electricity influences the charging behavior of plug-in electric vehicles (PEVs) and can be used to encourage a better PEV charging load distribution. The article contributes to the literature by providing a useful tool to assess the influence of electricity pricing on PEV charging behaviors, allowing better management and operation of urban transportation and power networks.

7. The electric vehicle shortest-walk problem with battery exchanges

Adler et al. propose an electric vehicle shortest-walk problem of finding the shortest electric vehicle routes from origins to destinations with minimum detouring to recharging/exchange stations. The problem is

formulated as a binary integer program. The authors consider two problem scenarios: the first is to determine the route to minimize the travel distance without any restriction on the number of battery recharge/exchange stops made, and the second is to determine the route with a restriction on the maximum number of battery recharge/exchange stops made. Both of these versions of the electric vehicle shortest-walk problem can be solved in polynomial time. The effectiveness of the algorithms used to solve the two versions is examined on randomly generated networks, and the results indicate that the algorithms are fast and efficient in terms of computing time. The authors also present a shortest route problem of finding routes that minimize driver anxiety, where the driver's anxiety level is defined as a monotonically decreasing function of the charge (fuel) remaining in the battery. This study has the potential to improve the planning and design of battery recharge/exchange infrastructures to minimize detouring.

8. Towards high-resolution first-best air pollution tolls: An evaluation of regulatory policies and a discussion on long-term user reactions

Kickhöfer and Nagel present a new simulation approach to estimating a high-resolution first-best air pollution toll in a large-scale real-world scenario of the Munich metropolitan area based on emission cost factors. A novel multi-agent transport simulation modeling approach is adopted to estimate the air pollution cost for each road link in the network. The resulting emission cost and welfare effects are used as benchmarks for the evaluation of a regulatory measure. The impact of a first-best emission toll is discussed by comparing the short-term and long-term behavioral reactions, particularly the role of more fuel efficient vehicles. The results show that the regulatory measure is less effective in terms of total emission reduction. The results also indicate that the long-term effect of emission reduction is dominated by the short-term effect and the assumed improvement in fleet fuel efficiency and that the influence of the resulting route and mode choice decisions is minimal. This study contributes to the literature by providing a new approach for evaluating the economic benefits of regulatory measures for air pollution.

9. Optimal charging strategies under conflicting objectives for the protection of sensitive areas: A case study of the Trans-Pennine corridor

Gühnemann et al. analyze the effects of different charging scenarios in environmentally sensitive areas by using a case study in Trans-Pennine corridor undertaken in Northern England. The authors extend the literature by considering the added dimension of institutional competition when road pricing is used simultaneously as a demand management tool in both an urban and an environmentally sensitive rural setting. The grid search approach is adopted to assess the optimal toll solutions under the global and local regulation scenarios. The analysis indicates that global cooperation regulation generates the maximum overall welfare of the region, while local regulation can lead to a "beggar my neighbor" policy and may reduce the region's overall welfare level. These results are useful to policy makers, as they demonstrate the fact that a road pricing strategy can be a successful demand management tool in combating local environmental problems and improving welfare if the strategy is implemented in a co-operative manner with surrounding areas.

10. Logistics cost and environmental impact analyses of urban delivery consolidation strategies

Lin et al. develop an alternative modeling framework for examining the effectiveness of urban delivery consolidation in reducing monetary logistics costs, energy consumption, and vehicle emissions from a strategic planning viewpoint, considering a number of operational and policy factors. The continuous approximation method is used to model urban delivery, and the motor vehicle emission simulator (MOVES) is used to determine energy consumption and vehicle emissions. The results indicate that the urban consolidation centre (UCC) could achieve potential monetary and environmental benefits by improving the use of vehicle capacity through consolidation, or by providing cheaper storage at the UCC. The study contributes substantially to the literature by demonstrating the capability of the alternative modeling method in analyzing urban freight policy, and will be useful for strategic freight delivery planning with the consideration of environmental sustainability.

11. Finding efficient and environmentally friendly paths for risk-averse freight carriers

Li et al. develop a freight routing model for optimal path finding considering a trade-off between three objectives: efficiency, reliability, and sustainability. MOVES is used to estimate the relationship between greenhouse gas emission rates and link speeds. The proposed modeling framework addresses inherent uncertainty by modeling link travel speeds as discrete random variables, while the risk-averse behavior of

freight carriers is captured by a second-order stochastic dominance relationship. The results indicate that (i) modeling emissions as a constraint appears more promising; (ii) optimal route choice depends on constraint type and benchmark choice; and (iii) emission and travel time reliability can be achieved with a certain risk premium. The proposed model and its results are useful for freight carriers in making routing decisions. The model also provides policy makers with an effective tool to predict or even influence the freight traffic distribution in the transportation network to achieve environmental sustainability.

12. Bundling of outbound freight flows: Analyzing the potential of internal horizontal collaboration to improve sustainability

van Lier et al. propose a discrete event simulation methodology for optimizing a horizontal internal collaboration across warehousing functions to reduce environmental and social costs on existing transportation networks. A case study is carried out to investigate the internal co-loading of a company with three product categories based on a collaboration approach. The methodology is used to estimate the outbound product flow of neighboring distribution centers for the purpose of evaluating whether a cross-dock would increase the fill level of trailers/containers. The results indicate that (i) shifting the workload to non-peak periods can improve capacity utilization; (ii) a cross-dock scenario can lead to an improvement in performance measures; and (iii) the reduction of trailer movements can potentially reduce external and internal transport costs, but remain limited without process changes. The proposed methodology and the results are useful for improving environmental sustainability in existing transportation networks and achieving sustainable logistics systems.

13. Multimode multicommodity network design model for intermodal freight transportation with transfer and emission costs

Qu et al. develop an intermodal freight transportation model that considers both intermodal transfers and greenhouse gas emissions. The model is formulated as a non-linear integer program to minimize the total transportation costs and is then converted to a linear mixed integer model using a linearization method. A case study of UK forms is performed. The results indicate that the proposed model can provide cost- and emissions-efficient ways of transporting commodities. This study has made the traditional logistic model more sophisticated by extending the model to consider greenhouse gas emissions. The proposed model provides planners and modelers a practical tool for designing optimal service networks and transportation routing with minimum transportation and emission costs.

14. Bicriteria optimization model for locating maritime container depots: Application to the Port of Valencia

Palacio et al. develop a bicriteria optimization model for selecting container depot locations in the hinterland based on the multicommodity capacitated location problem with balancing requirements. The objectives are minimizing the total system cost and the environmental effects induced by operating the container depots. The analytic hierarchy process methodology is used to assess the environmental impact, and the ε-constraint method is used to generate the optimal Pareto set for the problem. The model results are reported using a case study of the Port of Valencia. The results indicate that trade-offs are possible between both objectives and that the proposed approach is more sophisticated than the existing approach, obtaining significant cost improvements and reductions in the environment impact of depot operation. This study has developed an improved model by considering the environmental impact induced by depot operation. The advanced model is potentially useful for selecting optimum depot locations to minimize both cost and environmental effects.

15. The cost of environmental constraints in traffic networks: Assessing the loss of optimality

Lin et al. propose a criterion called loss of optimality, with a corresponding framework to quantify the influence of environmental constraints on an urban traffic network under the available control measures. The criterion is evaluated using a bi-level programming approach. The authors present a simple case study to demonstrate the concept of the proposed assessment framework. The results indicate the practicality of the framework under different types of environmental constraints and control measures. This proposed framework is useful and widely applicable for assessing the influence of environmental constraints on an urban traffic network under various control measures. The proposed metric criterion also provides policy makers with a general overview of the influence of environmental constraints on an urban traffic network.

16. Dynamic modeling of performance indices for planning of sustainable transportation systems
Maheshwari et al. develop a dynamic model to enhance the understanding of the interdependent behavior of transportation, economics, and environmental systems, and to assess the performance of the three systems. A non-linear modeling approach using concepts derived from classical predator-prey techniques is used to capture the nominal behavior of the three systems. The results indicate that the performance of transportation and activity systems shows a periodic pattern with a phase lag, while the performance of the environmental system shows a decreasing trend. The proposed model and its results are important in that they improve the general understanding of the behavior of the relevant systems, and help to facilitate better design and policy decisions. The approach is also practical and useful for researchers seeking to enhance non-linear models for better analysis of sustainable systems.

17. Reduced carbon and energy footprint in highway operations: The Highway EneRgy Assessment (HERA) methodology
Sobrino et al. describe an improved energy assessment methodology to assess the carbon and energy footprints of highway operations. The methodology uses the consumption model, adjusted with a correction factor to account for road gradient. This methodology provides a more comprehensive estimation of the footprint of traffic flows for particular highway sections under certain traffic conditions. A case study of a Spanish highway is presented for model validation. The results indicate that the model successfully estimates the carbon footprint of vehicles with sufficient accuracy. The proposed methodology provides policy makers with an effective decision-making tool for scenario assessment during both planning and design stages, as well as for assessing energy consumption and pollutant emissions during the operational phase.

18. Optimal 4-D aircraft trajectories in a contrail-sensitive environment
Zou et al. develop an aircraft trajectory design model to optimize aircraft trajectories in a contrail-sensitive environment in order to minimize the total flying cost. The model is formulated as a binary integer program, and allows for flight altitude and heading adjustment, and contrail information updating. Compared with existing models from the literature, the model allows greater flexibility in flight path design and enables optimal 4-D flight routing in a dynamic, contrail-sensitive environment. A novel approach is also adopted to quantifying climate impacts by converting them into monetary values. The results indicate that the optimal trajectory significantly depends on the time horizon chosen when estimating the climate impacts. They also show that shifting flight departure times to reduce contrail impacts is not justifiable, as this would increase costs associated with passenger delays and result in aircraft network congestion. This study is useful in providing valuable understanding of the critical factors and tradeoffs in trajectory design. The model and results are also useful to both flight operators and aviation authorities in managing air traffic.

The eighteen articles published in this special issue provide advanced applications, new approaches, or advanced quantitative techniques to enhance environmental sustainability in transportation networks. Various research topics are explored in this special issue, including bike network design, bike fleet allocation, multimodal network equilibrium, electric vehicles, road pricing, environmental impact assessment, discrete choice model and analysis, logistics strategies, freight routing and distribution, freight network design, and aircraft trajectory optimization. It is my hope that this special issue will inspire and stimulate new research initiatives from academics, researchers, and practitioners, and will contribute valuable ideas and knowledge towards developing a more sustainable and environmental friendly transportation system.

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