Multiobjective bilevel equilibrium model for traffic assignment

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Abstract— Traffic assignment is an important step for traffic planning, which predicts the network flow or travellers route choice. By solving a traffic assignment problem (TAP) one can promote a more efficient use of the available roads infrastructure, which is important to enhance sustainability of the transport system. The TAP is usually based on Wardrop's principles of route choice: under user equilibrium, travellers seek to minimize their own travel time, whereas in the system optimum the sum of generalized travel costs within the traffic network are minimized [1]. However, in an era where cities need sustainable mobility systems, it is crucial to study the environmental consequences of a selfish behaviour in a congested network. Moreover, from the government/decision-makers level, it is desired that both the total travel time and total emissions are minimized under a traffic assignment strategy [2]. Multiobjective optimization can be used for minimizing emissions along with total system travel time (see [3,4]). The present work suggests a novel modelling framework to allow traffic analysts to predict vehicle emissions for a given traffic flow on a road network through a multiobjective bilevel optimization model. It uses a volume delay function as objective for the lower level problem (user perspective), and system travel time and especially developed emission functions as objective functions on the upper level (system perspective).

First, new emissions-speed relationships were derived for passenger cars in an urban mode. Emission factor models were developed as quadratic functions with speed as independent variable with coefficients estimated from regressions, highlighting high emissions rates at low speeds, gradually decreasing at the midrange speeds, and again increasing for higher speeds. Then, a multiobjective bilevel optimization model is proposed for traffic assignment under user equilibrium and system optimum. In the lower level of the proposed bilevel model the user equilibrium is modelled to minimize the travel time, while under the upper level, a bi-objective is considered, taking into consideration the total travel time and the total emissions.

Results suggest that the proposed multiobjective bilevel model can reduce the system wide emissions, when compared to a single-objective traffic assignment. The proposed process allows a comprehensive evaluation of impacts and options of route choice decisions. In particular, it allows decision-makers to predict the users routes and resulting traffic volumes in the road network based on minimizing both the travel time and emissions, which in turn may reveal vulnerabilities that may affect the efficiency of the road network.

Keywords—traffic assignment; user equilibrium; system optimum; emissions; multiobjective bilevel optimization

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