The Netherlands Research School for Transport, Infrastructure and Logistics

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Multi-Objective Road Pricing: Multi-level Optimization and Game Theoretical Approach

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Road pricing which takes into account different objectives pursued by different stakeholders and road users.
Traffic externalities such as congestion, air pollution, unacceptable high noise levels, and safety cost are increasingly becoming problematic. Road pricing can be used as a tool to optimally distribute traffic on the existing infrastructure so as to reduce the cost of the mentioned externalities. We analyze from a game theoretical perspective the situation where various stakeholders, e.g., governmental ministries and insurance companies, ask for various - usually conflicting – road pricing schemes in order to meet their different goals. The problem is formulated as a multi-level program.

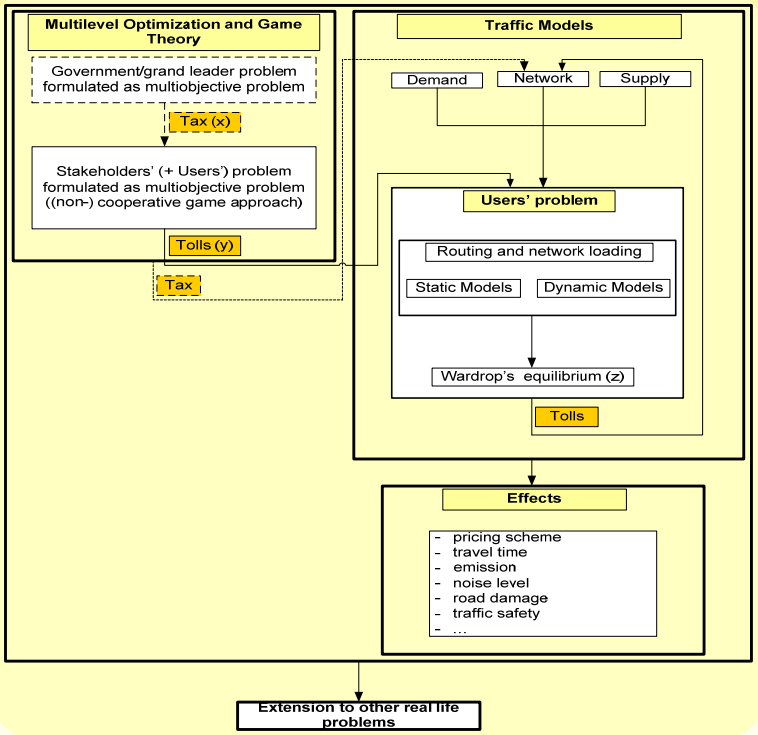
Motivation

- Single objective pricing alone may adversely affect the societal welfare.
- Poor acceptance of road pricing schemes due to unfairness in the proposed schemes.

Research Questions

- Under which conditions do stable tolling systems arise among the stakeholders.
- Can we design a tolling scheme such that actors at all levels of the multi-level game are contented.

The framework



Government, Stakeholders and Road users on level of tolls

$$\min_{x,y,z} \left(F_1(x,y,z),\ldots,F_k(x,y,z),f(y,z) \right) \qquad [Grand\ Leader\text{-}GL]$$

$$s.t \quad \tilde{G}(x,y,z) \le 0$$

$$\min_{y,z} F_1(x,y,z),\ldots,\min_{y,z} F_k(x,y,z) \qquad [Stakeholders]$$

$$s.t \quad G(x,y,z) \le 0$$

$$\min_{z} f(y,z) \qquad [Users]$$

$$s.t \quad g(y,z) \le 0$$

$F_i = Objective\ for\ stakeholder\ \ i,\ \ f = Users'\ objective$

$x = GL's\ \ parameter(tax),\ y = toll\ vector,\ z = flow\ pattern$

Results

- In general, Nash equilibrium (NE) does not exist among the stakeholders.
- NE which leads to Pareto optimal flow (cooperative outcome) can be induced on the stakeholders using mechanism design: there exist infinitely many tax vectors x that induce such optimal result.

Next research direction

- Cooperative model among stakeholders and profit allocation rules.
- Equity issues among stakeholders and road users.
- Validation of the models with real traffic data.

Conclusions

- Single objective optimization/road pricing may lead to a bizzare network situation.
- Game theoretical approach is a promising tool for this multi-objective road pricing problem.

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