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Resolving the property right of transportation emissions through public–private partnerships

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ABSTRACT

The application of public–private partnerships (P3's) in the transportation sector has grown in popularity worldwide. Despite this important shift in the provision of transportation service, there are clear gaps in knowledge about the impacts of P3 projects, especially on emissions from transportation systems as a whole. Not only should policy makers evaluate the emissions impacts from P3 projects, but they should also think about innovative models that address or charge for emissions into P3 contracts. This addition to P3 contracts could provide a new solution to the long-existing property right paradox: who owns (is responsible for) emissions from transportation systems? This study attempts to fill the research gap by analyzing these innovative models. Using the road network of Fresno, California, as our case study, we offer a number of interesting insights for policy makers. First, average peak emissions costs range from 1.37 cents per mile (the do-nothing case) to 1.20 cents per mile (profit-maximizing cases) per vehicle. Although emissions costs from the P3 projects are lowest for the profit-maximizing cases, the system-wide emissions costs of these cases are highest because of spillover effects. Second, charging project owners for the emissions costs of P3 projects is not an effective way to reduce emissions or the total costs of travel, especially on a VMT basis. Instead, the public sector should implement emissions-included social cost-based price ceilings. When employing these limits, project owners could still be charged for the emissions costs. Finally, using total travel time as the only objective function for evaluating P3 projects can be misleading. Several P3 projects have shown better outcomes using total travel cost with the inclusion of emissions and fuel consumption costs, instead of using total travel time as the only objective function.

Introduction

The increasing growth of private participation in the operation, maintenance, and financing of transportation infrastructure necessitates the search for more innovative and deliberate Public Private Partnership (P3) models/contracts/legislations. There are many potential P3 projects in the United States that would benefit from well-formulated P3 legislation, and consequently P3 contracts (Bel and Foote, 2009; Reinhardt, 2011).

Private sector involvement in the provision of transportation services has important implications for road networks (Rouhani, 2009). It is critical for financing (Engel et al., 2003; Engel et al., 2006; Chung et al., 2010; Bonnafous, 2010), but

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also has implications for service quality (Bel and Foote, 2009), for environmental impacts (Winkelman et al., 2010), and for social issues (Leruth, 2012; Tsamboulas et al., 2013). However, little effort has been made to develop theoretical models to analyze the emissions-related implications of such projects on actual road networks.

Not only should policy makers evaluate the emissions impacts from P3 projects, but they should also think about innovative P3 models that address or charge for the emissions in P3 deals. This addition to P3 contracts could provide a new solution to the long-lasting property right paradox: Who owns (is responsible for) the emissions from transportation systems? In fact, the point of regulation could be changed from the commonly-considered transportation users (drivers) or car manufacturers to road owners or operators (Rouhani, 2009). Governments could achieve more sustainable and efficient transportation systems by internalizing emissions costs since private operators (owners) will pass these costs on to transportation users, and this, in turn, will induce more efficient travel behavior from users in relation to their vehicles' emissions.

Charging road owners could be less complex than charging mobile and hard to trace transportation users, and eventually the road owners would transfer the costs to users (internalize the costs). Moreover, the transformation from public to private ownership could facilitate charging for emissions costs since the resulting decentralized system could offer more clearly-defined and exchangeable property rights (Quiggin, 1988). In many cases, the ownership of public roads is vague, involves multiple owners/layers, and is poorly regulated. By employing P3 projects along with the implicit ownership transformation, the public sector could charge private owners/operators for the pollution produced from their property.

Much of current theory about P3 projects has been developed using smaller networks and focusing on specific elements of privatization other than emissions. For example, theoretical models have been developed to study the effects of time-based (congestion) pricing, the decisions about maintenance and tolling (de Palma and Lindsey, 2002; de Palma et al., 2007), different ownership structures (Tan et al., 2010; Winston and Yan, 2011; Rouhani and Niemeier, 2011), various distributions of value of time considering multi-class user features (Yang et al., 2002; Wu et al., 2012), and the dynamics between a small set of public and private roads under various pricing and P3 options (Yang and Meng, 2000; Chen and Subprasom, 2007; Verhoef et al., 1996; de Palma and Lindsey, 2000).

Only a handful of studies have examined more complex networks. Zhang and Levinson (2009) simulated the evolution of a grid road network and evaluated the short-run and long-run network performances under various ownership structures (private/public and centralized/decentralized). Zhang (2008) developed an evolutionary model that analyzes the combination of pricing, investment, and ownership to study welfare impacts of road privatization on a large-scale network (the Twin Cities, Minnesota). Dimitriou et al. (2009) developed a game-theoretic formulation for the joint optimization of capacity investments and toll charges within general road networks, examining practical issues such as the regulation of tolls on privately operated highways. Using Fresno's existing transportation planning model, Rouhani et al. (2013) examined the effects of privatization on system performance measures and the differences between social cost prices and profit-maximizing prices.

Although many research studies have considered environmental impacts as significant factors in the analysis of P3 projects (Garvin and Bosso, 2008; Rouhani, 2009; Leruth, 2012), the impacts of P3 projects on emissions and fuel consumption have not been widely studied in detail and certainly not on a system-wide level. However, numerous detailed models have been developed to quantify CO_2 emissions, fuel consumption, and standard pollutant emissions produced from transportation networks in the general context (Midenet et al., 2004; Nesamani et al., 2007; Cortés et al., 2008). As one of the few studies, Daniel and Bekka (2000) modeled and estimated changes in vehicle emissions from highway congestion pricing in New Castle County, Delaware, using its travel demand model. The study found that partial pricing could increase emissions on unpriced substitutes and even aggregate emissions in the case of low price elasticities.

This study attempts to fill the research gap in the following areas: the quantification of emissions from P3 projects; the differentiation between profit-maximizing, traditional social cost, emissions-included social cost, and emissions-included profit-maximizing prices; and the exploration of the possible approaches to addressing emissions costs (i.e., charging project owners) into P3 contracts. Building on an earlier paper by Rouhani et al. (2013), we employ a distinctive modeling framework to analyze the above-mentioned issues using the transportation network of Fresno, California.

From a wide range of existing P3 models, this study focuses only on concession models that grant a private entity the right to collect tolls from an existing facility and might limit toll rates (Reason Foundation, 2009; Rall et al., 2010; Evenhuis and Vickerman, 2010).

Modeling framework

Benchmark model

The benchmark model is based on an earlier research (Rouhani et al., 2013) estimating the effects of concession projects on the road network of Fresno, CA, using the existing transportation planning model (employing Viper and TP+ as the main software programs). The benchmark model integrates the following modules: demand analysis, interactive profit maximization using game theory concepts, and modified traffic assignment.

Road-owners attempt to maximize their profit, which is the sum of the tolls gathered from the segments or the links of their road (or tolls on link i–j multiplied by the link's equilibrium flows for all the roads owned by firm k that comprise the F_k set, $(i,j) \in F_k$), minus the costs of gathering the tolls ($C_{Fk}(x_{ij})$) for firm k. The core of the benchmark model is the analysis of travel demand for each private operator. In practice, owners estimate their roads' demand functions which are based on their