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Parking enforcement policies for commercial vehicles

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ABSTRACT

Commercial vehicles are of particular interest in parking enforcement because of their heavy presence in central business districts and their recurrent behavior of illegal parking. To deter illegal commercial vehicle parking, enforcement policies are defined by the citation fine and level of enforcement. This paper investigates how rational carriers react to a policy under steady state equilibrium conditions. To model the equilibrium, the paper uses the theory of bilateral searching and meeting where enforcement units meet illegally parked commercial vehicles at a rate which depends on the size of the two agents (illegally parked commercial vehicles and enforcement units). In assessing policy effectiveness, two objectives are defined which are profit maximization and social cost minimization. With the two objectives, the paper presents three market regimes and studies the equilibrium of each market. The proposed model covers several gaps in the parking literature by introducing illegal parking behavior elasticity with respect to parking dwell time, level of enforcement, citation fine, and citation probability. The model is applied on a case study of the City of Toronto and the results show that the citation probability increases with dwell time and the level of enforcement. Increasing either the citation fine or level of enforcement will hinder illegal parking but the obtained profit remains approximately constant. Sensitivity analysis on the meeting rate elasticity shows that profits are low when both elasticities are either high or low.

1. Introduction

Illegal parking leads to adverse societal impacts such as reduced traffic speeds, loss of revenue from legal parking, and more accidents caused by safety violations. In response to these detrimental consequences, policies are imposed to alleviate illegal parking. Parking enforcement, the most prevalent policy, has been implemented in major cities for many years. Clearly, an effective enforcement plan requires an in-depth understanding of the causes and patterns of illegal parking. Commercial vehicles (CV) are of particular interest in parking enforcement because of their heavy presence in central business districts and their recurrent behavior of illegal parking. In 2014 alone, a total of 691,240 tickets were issued to CVs in Toronto, Canada, almost a quarter of the total number of parking tickets (City of Toronto, 2015). The CV tickets generated $30,516,000 for the city which the carriers are willing to pay as part of the high cost of the "last mile" in the supply chain. To exacerbate the situation, illegally parked CVs create other problems such as increased traffic delay and unsafe conditions. Estimates show that illegal CV parking results in approximately 47 million vehicle-hours of delay each year in the United States, making illegal CV parking the third leading cause of delay behind construction and crashes (Han et al., 2005).

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Moreover, CVs commonly park on bike lanes in order to reduce their egress time to the delivery destinations. In New York City, an average of 14% of CV on-street parking results in a conflict with a cyclist (Conway et al., 2013). With all these complications, parking enforcement policies must be designed with consideration of illegal CV parking.

The three fundamental components of any parking enforcement policy are detection technology, level of enforcement, and the citation fine. Detection technology is the method of finding illegally parked CVs and the two prominent methods are human[1] surveillance and video detection (Mithun et al., 2012); level of enforcement is the density of the enforcement units (e.g. cameras or on-foot officers) in the region; and citation fine is the imposed penalty for illegal parking. While the choice of the detection technology is a long term decision, policy-makers generally have more power over choosing the level of enforcement and the citation fine. The City of Toronto, for instance, has practiced human surveillance since the initiation of its enforcement policy but has changed the citation fine many times such as in 2015 when parking fines during peak periods were raised from $60 to $150 and the number of parking enforcement officers were increased as well (Powell and Clarke, 2015). Hereafter, we use the term "policy" to refer to a chosen level of enforcement and the citation fine.

Enforcement policies can influence the parking behavior of CVs. A large fine can deter CVs from parking illegally whereas a small fine may be considered by carriers as "the cost of doing business" (Nourinejad et al., 2014). Similarly, a high level of enforcement increases the probability of receiving a citation thus discouraging illegal CV parking. For the city, choosing the right policy depends on what objective is pursued. Two common objectives are profit maximization and social cost minimization. The citation profits are substantial in many cities. In 2013, New York City, Los Angeles, and Chicago each generated 534, 250, and 176 million dollars, respectively. In some instances, target profits are defined annually and policies are devised to reach them. Profit maximization must consider the reactive behavior of CVs as well. For instance, increasing the fine does not always lead to a higher profit because some CVs might start to park legally in order to avoid the penalty. As the second objective, social cost is seldom quantified but equally important. The extra traffic delay that CVs generate is cumbersome for society. The two objectives are not naturally obtained from one policy. The policy that maximizes profits may compromise social welfare. In this paper, we formulate the two objectives, model the reactive behavior of CVs, and present the tradeoff between the two objectives.

This paper is organized as follows. A review of research on illegal parking is presented in Section 2 and the gaps in the literature are highlighted. A model of parking enforcement with special treatment of CVs is presented in Section 3. In Section 4 two policy objectives are formulated and three market regimes are discussed. Numerical experiments are performed in Section 5 using the City of Toronto as a case study. Conclusions are presented in Section 6.

2. Background

Despite the abundance of research on parking enforcement, most studies provide only a descriptive analysis of illegal parking such as on-street parking meter behavior (Adiv and Wang, 1987), illegal parking behavior in central business districts (Bradley and Layzell, 1986; Brown, 1983), impact of illegal parking on local businesses (May, 1985), impact of parking fines on public transportation ridership (Auchincloss et al., 2014), CV illegal parking behavior (Wang and Gogineni, 2015; Wenneman et al., 2015), and non-CV illegal parking in loading bays (Aiura and Taniguchi, 2005; Alho and e Silva, 2014). A review of descriptive models is presented in one (if not the only) literature review of parking enforcement by Cullinane and Polak (1992) that focuses on the relationship between illegal parking and parking controls and the factors that influence the choice of illegal parking.

Descriptive models, although useful for identifying the factors that influence illegal parking behavior, do not provide a tool for finding the optimal enforcement policy. The need for prescriptive parking enforcement models is advocated in a recent literature review by Inci (2014) where the need for theoretical modeling techniques is stressed. In theory, the parking enforcement problem is an inspection game where the enforcement units are the inspectors and the CVs are the inspectees (Ferguson and Melolidakis, 1998; Avenhaus and Canty, 2012; Sasaki, 2014). In the classical inspection game, there are two players called the inspector and the inspectee. The inspector's strategy space is to audit the inspectee or not and the inspectee's strategy space is to violate the rules or not. The conditional probability that a violating inspectee is caught (i.e. the citation probability) is equal to the audit probability of the inspector. In the illegal parking problem, however, the citation probability (i.e. probability of catching a violating inspectee) is a function of how long the illegal CV parks (i.e. the dwell time) and the number of enforcement units. An increase in either the level of enforcement or the dwell time of the illegally parked CV increases the citation probability. This feature of the illegal parking problem merits an appropriate modeling approach.

To accommodate this feature in the inspection game, we use the concept of bilateral searching and matching (or bilateral meeting) which models the meeting friction between two sets of agents. Examples of bilateral meeting in economics include taxi-passenger meeting (Yang et al., 2010), buyer–seller meeting (Burdett et al., 2001), and employer–employee meeting in the labor market (Andolfatto, 1996; Berman, 1997). The meeting function is formulated so that the meeting rate of the two agents is a function of the number of agents. For instance, the rate of taxis meeting passengers depends on how many vacant taxis and passengers are available (Yang et al., 2010). A review of the bilateral meeting function is conducted by Petrongolo and Pissarides (2001). In this paper, we use the bilateral meeting function to model the searching friction present in the

[1] Human surveillance includes on-foot, cycling, and driving officers.

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