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Tradable mobility permits in roadway capacity allocation: Review and appraisal

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ABSTRACT

The paper presents a comprehensive review on a variety of tradable mobility permits (TMP) schemes that are proposed as an innovative way of allocating roadway capacity. The study develops a comparative analysis and a qualitative evaluation to identify the similarities and variations among various TMP schemes. The paper summarizes both the strength and the weakness of different TMP schemes with respect to congestion reduction, market mechanism, and equity issues. A comparison between three typical TMP schemes and congestion pricing (CP) yields the following main conclusions: (i) there is no general superiority between the TMP schemes and the CP; (ii) various TMP schemes are unlikely to be combined into a general one, and should be separately designed for the particular objective and application condition; and (iii) different TMP schemes have different parts to be emphasized in the system design. The paper points out the implications for designs of pragmatic TMP schemes and the future research.

1. Introduction

Roadway capacity is restrained due to the scarcity of the lands, and thus roadway capacity allocation plays a significant role in balancing roadway usage and alleviating traffic congestion. The basic idea of roadway capacity allocation is to assign the right-of-way (ROW) to different roadway users on the basis of certain allocating mechanism so as to manage the roadway traffic more efficiently. For instance, signal controlled intersections allocate the ROW to vehicles at conflicted approaches through rotating signal timing phases; bus lane is designated for bus only; and high-occupancy-vehicle lanes are reserved for vehicles with two or more occupants. As one of the most innovative capacity allocation approaches tradable mobility permit (TMP) not only assign use rights to roadway users as traditional measures do, but also endow trade rights to activate market mechanism to distribute the roadway-use rights to travelers with the highest value. The concept of TMP stems from the notion of tradable permit (TP), which is also called marketable/transferable permit. It is generally accepted that the TP approach is originally proposed by Dales (1968) targeting water pollution control. Since then, numerous TP schemes have been developed and applied in the fields of environmental regulations (Hahn and Hester, 1989; Hepburn, 2006; Stavins, 2007; Tietenberg, 1980, 1985, 1994, 2006a) and transport emission control (Albrecht, 2000; Dobes, 1998; Raux, 2002, 2004; Raux and Marlot, 2005; Wang, 1994). In the field of transport capacity allocation, early implementation of the TP approach can be found in the studies of airport slot allocation (Bouckaert, 1993; CAA, 2001; Howe et al., 2003; Morrison and Winston, 1989; Rassenti et al., 1982; Starkie, 1998; Steinen, 2003; Wit and Burghouwt, 2008), which particularly aim to improve the efficiency of runway usage. Specific applications of the TP approach in roadway capacity allocation can be traced back to the work by Goddard (1997) and Verhoef et al. (1997), followed by significant amounts of researches including: Viegas (2001), Kockelman and Kalmanje (2003), Gulipalli et al. (2004), Kalmanje and Kockelman (2004), Hepburn (2006), Akamatsu (2007), Buitelaar et al. (2007), Frisoni (2007), Raux (2007), Gulipalli and Kockelman (2008), Wada and Akamatsu (2008, 2010), Iaione (2009), Ch'gn (2010), Fiorello et al. (2010), Yang and Wang (2011), Nie (2012), and Wang et al. (2012). It is emphasized in the paper that the term TMP specifically refers to roadway-use TP, and the literature review is limited to the TMP schemes only.

Early TMP studies mainly focused on the conceptual developments, where various TMPs are proposed by different measures of delineating roadway capacity, such as driving day (Goddard, 1997), vehicle-mile traveled (Verhoef et al., 1997), and access rights at roadside control points (Wong, 1997). Recent studies begin to apply quantitative analysis by means of modeling (Akamatsu,

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2007; Frisoni, 2007; Kalmanje and Kockelman, 2004; Nie, 2012; Raux, 2007; Wang et al. 2012; Yang and Wang, 2011) and simulating exercises (Fiorello et al., 2010).

Four of the above-mentioned studies are discussed under specific city settings, including the Credit-based Congestion Pricing (CBCP) in Austin (USA) by Kockelman and Kalmanje, (2003), the Tradable Driving Day Rights (TDDR) in Mexico City (Mexico) by Goddard (1997), the Genoa Mobility Rights (GMR) in Genoa (Italy) by Fiorello et al. (2010), and the Tradable Driving Rights (TDR) in Lyon (France) by Raux (2007). All four cities have serious problems of traffic congestion and air pollution. In Mexico City, Genoa, and Lyon, congestion/road pricing (CP) was proposed and tested, but failed to achieve the permanent implementation due to low public acceptance (Raux and Souche, 2004; Ieromonachou et al., 2006). Genoa was the only city to officially conduct simulation and evaluation on TMP (i.e., GMR) scheme as an alternative to CP with its regional planning model, while the other case studies were discussed under academic circumstances.

In general, the proposed TMP schemes share five common features: (i) the total quota of TMPs available in study area is predetermined; (ii) an initial endowment allocates the permits to the selected receivers; (iii) permit holders are allowed to exchange their quotas in the market or directly use for accessing roadway; (iv) roadway usage consumes the permits, and the consumption rates are differentiated by time, place, and vehicle's characteristics (e.g., vehicle size); and (v) enforcements are necessary to ensure the permits being consumed or traded validly. The Organization for Economic Co-operation and Development (OECD, 2001) summarized the advantages of the TMP approaches as opposed to the pricing or taxation approaches: (i) a permit system is more effective in terms of quantity control than pricing or taxation, of which the outcomes are uncertain due to lack of knowledge of various agents' responses to the price/tax; (ii) a permit system is more appropriate in the cases where agents are more sensitive to quantitative criteria than the price in terms of restraining their consumptions; (iii) free endowment of the permits enhances the acceptability of the schemes to the public; and (iv) the tradability of the permit allows the traders other than the government to receive benefits by reducing their consumptions and selling additional permit quota. Nevertheless, few city authorities have reportedly endorsed TMP scheme in an official manner. This phenomenon may be partially explained by decision-makers' lack of knowledge about the innovative method and the controversy of the scheme effects. Even the TMP advocators (e.g., Buitelaar et al., 2007; Goddard, 1997; Nie, 2012; Verhoef et al., 1997) admit that the TMP scheme manifests itself with some disadvantages, e.g., high administrative costs due to the complexity of the system, extra information costs of searching potential traders, and additional transaction costs in the trading market. Therefore, it is necessary to compare the pros and cons of the proposed TMP schemes.

The paper aims to provide a comprehensive review on various proposed TMP schemes, compare detailed system designs and overall functions, and consequently explore the future research prospects on the subject. In doing so, one of the hurdles is to compare the contexts (e.g., the target city and its socioeconomic characteristics) of the TMP schemes, because the majority of the schemes (except the CBCP, TDDR, GMR, and TDR) are currently at the theoretical stage without specific implementation contexts. Therefore, the review focuses on comparing the system designs and functions of the TMP proposals, and revealing the applicability of TMP schemes under three given typical contexts (i.e., cordon congestion area, freeway, and commuter corridors). The paper is organized as follows. Section 2 presents the development of the various concepts of TMP. Sections 3–5 discuss the TMP schemes with respect to three scheme stages: the delineation, the initial endowment, and the implementation, respectively. Section 6 summarizes the strength and weakness of the scheme functions. Section 7 provides concluding remarks and recommendations for the future research.

2. Development of the tradable mobility permits

Most of the TMP proposals are non-monetary and the only exception is the CBCP by Kockelman and Kalmanje (2003). Compared with the conventional CP, the CBCP scheme is revenue-neutral and prone to be accepted by the general public; revenues collected in the CBCP scheme would be uniformly and monthly redistributed to all licensed drivers. As a result, drivers with average amount of travel may balance out in the CBCP scheme and the below-average drivers may gain some monetary benefits, whereas drivers who travel a lot have to pay for their overuse of the roadway capacity. Potential equity issues, however, may exist among the selected receivers. Considering that not all the licensed drivers own vehicles, they may benefit from selling the their quotas without any contribution of roadway usage reduction, and the vehicle owners are actually paying for those who have no chance to occupy roadway capacity to stay off the congested roads.

The non-monetary TMPs have one exception—the tradable fuel permits (TFP) proposed by Verhoef et al. (1997), which treats fuel consumption as a proxy to roadway capacity consumption. Under the TFP framework, motorists are required to buy fuels by permits issued by the authorities. The TFP may be effective in traffic emission control, but has limited effectiveness on roadway capacity allocation and congestion mitigation in the long run, because motorists can circumvent the quantitative restrictions and maintain their roadway capacity consumptions by driving fuel-efficiency or alternative fuel automobiles.

Non-fuel-based TMPs are tightly associated with the properties of roadway capacity usage, such as trips and vehicle miles traveled (VMT), as well as demand characteristics (e.g., time of day and place of travel). Non-fuel-based TMPs can be further divided into time–place specific TMPs and time–place dependent TMPs. The former TMPs pre-define spatial and temporal dimensions of access permission into roadway network. Wong (1997) is the first to propose a time–place specific TMP, the booking access rights system (BAR) analogous to the airline seat booking system, in the context of highway capacity allocation. In the BAR scheme, travelers have to obtain their access rights in advance, and the highways are exclusive for those who hold the access rights and show up at the pre-specified time. Though BAR highway operators can ensure the traffic not to exceed the highway capacity by pre-specifying the total amount of the access rights available during certain time period. The author does not allow the tradability of the access rights. On the contrary to the nontrade BAR, Buitelaar et al. (2007) develop a tradable access rights (TAR) scheme. Akamatsu (2007) proposes a scheme of TBP with an auctioning system rather than the booking system, and emphasizes the application to roadway bottlenecks (e.g., bridges). Main concern about these time–place specific TMP schemes is that roadway network may produce a tremendous number of distinct permits for every roadway link and each time interval, which require a very sophisticated booking (auctioning) system and trading market. Verhoef et al. (1997) and Yang and Wang (2011) express that it was practically inconceivable how roadway users could schedule and bargain over (e.g., booking or bidding) permission for roadway usage at each time and place along their daily trips. In addition, transportation systems with booking services provide the waiting halls for queuing customers to receive services, e.g., the airport departing halls, because customers have to schedule an early-arrival time to overcome journey-time uncertainty and avoid