Private financing and mobility management of road network with tradable credits

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ABSTRACT

 Tradable credits have been recognized as a powerful instrument and are increasing used in many fields. This paper employs the tradable credits scheme on traffic mobility management and private provision of public transportation infrastructure through a novel kind of private financing of public road: build-equity-credit (BEC) scheme, hoping to achieve a triple win. Namely, the government can achieve its objectives (e.g. construction of the new road, desired traffic condition, certain vehicle emissions threshold) without its own capital, the private firm can receive its expected profit with less public's resistance and the travelers can enjoy less congested traffic with a negligible cost. Moreover, many issues that occurred upon the termination of the traditional private financing (e.g. build-operate-transfer) scheme, such as severe congestion, explosion of travel demand and lack of management and maintenance, can be avoided in BEC. A general bi-level programming problem is formulated to model the determination of capacity of the new road and the tradable credits scheme in BEC scheme. The properties of several different BEC scenarios are investigated. Generally, the link service level in BEC is not constant but depends on multiple factors. Under some conditions, the total market value of the credits charged on the new link can offset its construction cost and the profit of the private firm can always be nonnegative. © 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Over the past decades, the participation of the private sector in transport infrastructure services has become popular worldwide, which rebalances the roles of public and private sectors played in public service delivery. Such partnerships between the public sectors and the private sectors are often known as public-private partnership (PPP). The interest in PPP is partly driven by the fact that the required huge amount of investment for providing and maintaining transportation infrastructures has imposed a great challenge to the governments worldwide. The increasingly tight government budgets further aggravate this situation. The government, therefore, is in favor of having the private investors to play an increased role in the investment and development of transport infrastructure. Privatization is further supported by the popular view that private firms operate more efficiently because of their profit motivation, thereby lowering the cost of construction and providing better service level (Yang and Meng, 2000).

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Generally, PPP is arrangements typified by joint working between the public and private sectors for a long term (HM Treasury and OGC, 2005). Based on different combination of services, roles and responsibilities and different financing methods between the government and the private sectors, there are multiple alternatives for PPP. Mu (2008) synthesized the alternatives of PPP, which includes many different forms: design-bid-build (DBB), service contract, design-build (DB) design-build-operate (DBO), design-build-operate-maintain (DBOM), build-operate-transfer (BOT), build-operate-own (BOO), design-build-finance-operate (DBFO). A two-dimension framework (Fig. 1) is used to depict these alternatives. The horizontal axis stands for the continuum of delivery methods measured by the degree to which the elements (design, financing, construction, operation, maintenance) of PPP projects are unbundled or bundled with one another, while the vertical axis stands for the continuum of financing method measured by the degree to which public sector or private sector undertakes the financing responsibility.

Build-operate-transfer (BOT) is one of the most popular options of PPP, where a private firm builds roads at its own expense. It then operates and charges the travelers who use the roads during a specified period to recover cost and/or receive profits and finally, these roads will be transferred to the government. There are many benefits of using BOT for transport infrastructure investment. For example, as mentioned above, it is widely believed that the private provision of roads can provide more efficient operation and management of transportation facilities. Also, the public sector, facing taxpayer resistance, may simply be unable to finance facilities that the private sector would be willing and able to undertake for a profit. Furthermore, almost all users can benefit from the BOT project, even those who do not use these new roads would benefit from reduced congestion on the old ones (Yang and Meng, 2000).

Given the advantages of BOT, it has attracted fast-growing interest in both theory and practice. Among the existing literature about BOT, many analyses have focused on the capacity choices and tolls setting as well as the profitability and social welfare gain (e.g. Yang and Meng, 2000; Lindsey and Verhoef, 2001; Yang and Huang, 2005; Lindsey, 2006) and also, properties of link service level and self-financing have been well investigated. It has been proved that, under certain assumptions, the link service level in terms of the volume-to-capacity ratio, offered by a profit-maximizing private firm on a private road is constantly equal to that under social optimum (Xiao et al., 2007; Yang et al., 2009; Tan et al., 2010; Wu et al., 2011; Wang et al., 2013; Niu and Zhang, 2013). Yang and Meng (2002) showed that self-financing holds for general network under some conditions.

While being popular, BOT scheme suffers from a few social, political and technical issues. Evidences show that many BOT projects in China continue to charge tolls for many years after the concession period is ended. This has caused the public’s questioning of corruptions and has met great objection and criticism although many firms argue that the tolls are used for further management and maintenance (e.g., Zhang, 2014; Xiao and Cao, 2014). However, if the toll charge is ceased, questions emerge, such as lack of maintenance and management, enormous congestion, and explosion of travel demand (Gu, 2013). For example, the Capital Airport Expressway in Beijing attracted forty percent more traffic flow after it stopped charging drivers, which led to heavy traffic congestion almost from 6 a.m. until 6 p.m. (Deng, 2011). It is impossible to recharge the road now for social and political reasons but leaving it alone results in great efficiency losses. Furthermore, to be equitable, the construction costs of the new road should be borne by all those who benefit from the increased traffic efficiency. However, as mentioned above, although all travelers can benefit from the BOT project, the construction and maintenance costs are only borne by travelers who use the new transport infrastructure. This may be unfair for travelers who bear a significant part of the huge construction costs by paying the toll charge, especially for the travelers who have no alternative roads. This is also one of the major reasons that the BOT scheme is rejected by the public.

Another concern with BOT project is that the government will lose control of the new transportation infrastructure during the concession period under operations of the private firm. The government thus faces difficulty in integrated planning, management and operations of the whole transportation infrastructure system. It is also very difficult for the government to deal with some unexpected situations. A noteworthy example is the Fifth Ring Road in Beijing. When the Fifth Ring Road in Beijing was completed and tolled in 2003, the average flow was only 200–300 veh/h while its capacity was 3000 veh/h. The usage of the road and the resulting daily toll revenue was far below the planners’ estimation, leading to a very embarrassing situation. Eventually, the government had no choice but ceased the tolling. However, because the Fifth Ring Road was a BOT project engaged by a listed company, the government had to buy back the project for full control. As a result, all parties suffered great losses (Zhang, 2004).

In view of these issues, this study proposes and examines a new PPP alternative: build-equity-credit (BEC), where tradable credits are employed to substitute the road tolls. BEC is also a form of commercial and private provision of transportation infrastructure. A private firm builds the new road at its own expense. However, different from BOT, the private firm does not operate the new road with toll charge but instead is granted some equities of the whole road network system as a reward for its construction. At the same time, the government will operate the road as well as the whole road network system by designing a new or redesigning an existing tradable credit distribution and charging scheme for achieving a predefined quantitative objective (e.g. social welfare maximization, a certain vehicle emissions threshold control). As a stockholder, the private firm will receive a given amount of tradable credits every period. The rest of the credits will be distributed to all the eligible travelers. Travelers pay credits to use the roads and can freely trade credits in the credit market. The private firm sells its credits in the credit market to gain profit. Therefore, every traveler in the network, regardless of their usage of the new roads, will undertake a minor part of the construction costs. After the private firm gains expected profit, the equities it owns will be transferred to the government but the tradable credit distribution and charging scheme will continue to prevent severe congestion and explosion of travel demand. The government can also keep some credits to sell in the market to
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