Transportation Research Part B 85 (2016) 56–69

Contents lists available at ScienceDirect

Transportation Research Part B

journal homepage: www.elsevier.com/locate/trb

Optimal choice of capacity, toll and government guarantee for build-operate-transfer roads under asymmetric cost information

Shasha Shi[a], Yafeng Yin[b,*], Xiaolei Guo[c]

[a] Business School, Central South University, Changsha, PR China
[b] Department of Civil and Coastal Engineering, University of Florida, Gainesville, FL, United States
[c] Odette School of Business, University of Windsor, Ontario, Canada

ARTICLE INFO

Article history:
Received 26 March 2015
Revised 26 November 2015
Accepted 26 December 2015
Available online 22 January 2016

Keywords:
Build-operate-transfer
Road capacity
Pricing
Government guarantee
Concession contract
Asymmetric cost information

ABSTRACT

The private provision of public roads via the build-operate-transfer (BOT) mode has been increasingly used around the world. By viewing a BOT contract as a combination of road capacity, toll and government guarantee, this paper investigates optimal concession contract design under both symmetric and asymmetric information about the marginal maintenance cost of private investors. Under asymmetric information, the government guarantee serves as an instrument to induce a private investor to reveal his true cost information. Compared with the situation under symmetric information, the government will suffer a loss of social welfare; the private investor will charge a higher toll that increases in his reported marginal maintenance cost, and specify a lower capacity that decreases with the reported cost. The results also show that the private investor obtains extra information rent beyond the reservation level of return and the rent decreases with his reported cost. However, the resulting volume-capacity ratios of the BOT road under both information structures are the same.

1. Introduction

Engaging private investors and entrepreneurs in constructing and operating transportation facilities has emerged as one of the most viable options for transportation infrastructure provision, as governments are facing tightening fiscal budgets and private investors could build and operate roads at lower costs than the government sector. Moreover, according to the self-financing theorem, if a new road is privately provided as an "add-on" to an existing road network, and it is to be paid by road users who are willing to patronize it, all its cost will be covered by the toll revenue and all the stakeholders of this private road would gain related benefits (e.g., Yang and Meng, 2000). Perhaps for all these reasons, governments have increased their reliance on private funds to build and operate transportation facilities.

A typical form of private–public partnership is the build-operate-transfer (BOT) concession under which a private investor would build and operate a new road at his own expense and in turn receive the revenue from charging road tolls for a pre-defined concession period and then transfer it to the government sector. As such, BOT roads involve two critical stakeholders: the government and private investors. For the former, social welfare of this new road is of great concern, while the

* Corresponding author. Tel.: +1 352 294 7805.
E-mail address: yafeng@ufl.edu (Y. Yin).

http://dx.doi.org/10.1016/j.trb.2015.12.019
0191-2615/

latter are interested in its profitability, which is a tradeoff between the profit they could receive from operating it and the risk they must assume. The allocation between social welfare and private profit depends on a long-term concession contract between the government and the private investor. A typical concession contract includes several fundamental components such as the concession period, road capacity, toll rates, and government guarantee. Each of them is critical in determining whether a BOT road is socially feasible and profitable to the private investor.

A number of previous studies have examined various issues related to BOT road projects. Some are dedicated to concession contract schemes and the discussions have primarily focused on the choice of capacity and toll charge to make a tradeoff between social welfare and private profit. In a general equilibrium context, Viton (1995) looked into the profitability of a BOT road in a network with a single BOT road and a single parallel public road. Yang and Meng (2000, 2002) formulated a bi-level programming model to analyze the profitability and social welfare gain of a single BOT road in a network, and calculated the optimal combination of toll and capacity under different conditions. Chen et al. (2003) integrated risk analysis and network optimization into a stochastic optimization model, and analyzed the optimal combination of toll and capacity under demand uncertainty. Guo and Yang (2009) designed the optimal concession contract, a combination of concession period, toll charge and capacity, to maximize social welfare, while satisfying the profit constraint of private investors. Tan et al. (2009) extended the study by considering road deterioration and maintenance and found that an optimal pricing policy requires toll to increase over time to reduce traffic load due to the time-increasing and load-increasing maintenance cost. Tan and Yang (2012) further considered demand uncertainty and investigated the full and partial flexibility of concession contract based on ex post contract adjustment. In a related effort, building upon a property of constant volume-capacity ratio of private toll roads (e.g., Xiao et al., 2007; Wu et al., 2011a; and Wang et al., 2013), Wu et al. (2011b) formulated and solved a tri-level program to optimally select highway projects for BOT development to improve social welfare while ensuring the projects marketable.

As private investors will gain some monopoly rights over road infrastructure assets during a pre-determined concession period, the government sector may need to protect the public interest by imposing regulations. Subprasom and Chen (2007) pointed out that both the price control regulation and equity regulation would cause a BOT road to be financial infeasible. Tan et al. (2010) investigated a variety of regulatory regimes to analyze the behavior of private investors, and found that price-cap, rate-of-return and capacity regulations all resulted in inefficient outcomes, while both the demand and markup charge regulations lead to Pareto-optimal outcomes.

Lastly, a few attempts have been made on auction mechanisms of BOT roads. Engel et al. (2001) proposed a new auction mechanism for highway franchise based on the least present value of revenue, and found that the mechanism would resolve the winners' curse and suppress ex post opportunism of the regulator and concessionaire as well as opportunistic behaviors of deliberate underbidding and contract renegotiation. Nombela and Rus (2004) proposed a franchising mechanism based on flexible term contracts and bids for total net revenue and maintenance costs, and suggested that this mechanism, compared with a fixed term mechanism, would select more efficient concessionaires. Verhoef (2007) studied welfare impacts of franchising regimes for congestible highways, and found that the patronage-maximizing auction is no longer optimal when considering a simple two-link network with one BOT road and the other unpriced parallel or serial road. Ubbels and Verhoef (2008) analyzed the welfare consequences of four different auction rules and reported that a bid with the minimization of price on the tolled road leads to very promising results in terms of welfare for auctions without subsidies; when allowing for subsidies, the best bid appears to involve the minimization of generalized travel costs comprising the toll on the new road and the subsidy divided by total traffic demand. Vassallo (2010) evaluated the effect that the discount rate established by the government in the bidding terms has on traffic risk allocation, and revealed that the lower the discount rate is, the larger the traffic risk allocated to the concessionaire will be.

A critical assumption made in most of these previous studies is that the government has complete information about private investors and thus can design concession contract schemes accordingly. This is rarely true in practice where private investors often possess information advantage regarding their efficiency and capability (Auriol and Picard, 2013). Specifically, the construction and maintenance costs of a particular road are affected by a number of factors such as market price of materials, labor cost, traffic loads, inflation and weather conditions, which are very difficult for both the government and the private investor to pre-specify (Small et al, 1989). However, the costs also depend on the choice and application of technology by the private investor, his pursuit of innovation in materials, processes and management, and his experience with other relevant projects (Zietlow and Bull, 1999). Therefore, the government sector is exposed to information asymmetry with respect to the efficiency and capability of the private investor. The government also suffers from another type of information asymmetry due to hidden actions by the private investor after a contract has been signed (Bolton and Dewatripont, 2005; Laffont and Martimort, 2002).

The information asymmetry between the government and the private investor has a significant impact on the efficiency of a concession contract. Ignorance of such information asymmetry can make it difficult for the government to fulfill a contract at the operation stage, and contract renegotiation consequently occurs. Recognizing that the concession contract variables determined in the complete information context do not necessarily yield optimal outcomes, we relax in this paper the complete information assumption and derive the optimal decision for the government on the selection of capacity, toll and guarantee. In line with Guo and Yang (2008), the concession period is assumed to be pre-determined. The government guarantee is considered in this paper as an incentive scheme in forming a BOT contract under asymmetric information. We firstly formulate a social welfare maximizing problem to optimize contract variables as well as ensuring the private investor to receive a reservation level of utility, which can be viewed as the symmetric information model. We show that