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16. Abstract

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Valuing Real Estate Externality-based Option in Development of Transit System Projects

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Capital-intensive transit projects rely on strong public support and availability of funds. While the general public has become a strong advocate for transit systems, budget shortfalls and financial constraints are still resulting in delays in project delivery. In such business environment, the public sector has an opportunity to partner with the private sector to deliver and operate needed infrastructures. In public-private arrangements, the private sector typically is unwilling to accept the system ridership risk, making such projects financially unfeasible. However, transit projects undoubtedly create value that is not internalized by the developer. The completion of a transit system not only increases the values of properties in the affected area, but also brings incremental tax revenue to the public sector. Thus, some of this newly created value can be shared with the private sector to make the project financially feasible. The objective of this paper is to develop a method for designing externality-based option and a model for its valuation. The proposed valuation model is based on the concept of auctions, where the price-jump results from the introduction of the new transit system. The numerical example results show that externality-based option could reduce private sector risk and add value to the private developer, making transit project more attractive.

DISCLAIMER

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EXECUTIVE SUMMARY

The value of having an efficient system has been witnessed by the public, at least a majority of people in large metropolitan areas. In order to solve urban environment problems and issues, such as traffic congestion, air pollution, transit system has been an increasingly attractive transportation alternative to passenger vehicles. Hence, while the support for the transit system project from public sector grew, the capacity of fund to finance it declined. This problem could be solved by partnership between public and private sector through the contractual instrument known as Public-Private Partnerships (PPPs). However, in such settings, the private sector is often unwilling to accept the revenue risk or the system ridership risk. Thus, it is necessary to show private sector that the risk considering revenue would be mitigated and the benefit from investing the transit system project. This report advocates that following the completion of a transit system the value of surrounding real estate increases as transit access is a highly valuable feature, thus there is a positive externality which results in an increase in property tax revenue for the public sector to utilize Tax Increasing Financing (TIF). This research proposes an auction-generated price model (the first-price sealed-bid auction) to capture dynamic changes in real estate prices and the impact of a new transit system on property values. Such an approach is capable to capture key supply-demand characteristics of the market in valuation process. The result also shows that the auction-generated price is not only depended on the feasible number of bidders, but also the average weighted upper limit of bidders' maximum Willingness to Pay (WTP) interval. Then, an externality-based option is presented and valued suggesting that an option (contingent claim) could be designed by the public sector to provide a part of that "almost certain value" from the tax increment revenue to the private sector to mitigate the risk that private sector is worried about considering future revenue. As a result, public sector (transportation agencies) could enhance financial support from private sector for project development by offering this externality-based option because this option acts as a risk mitigation instrument to reduce the uncertainty in future project value.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Capital-intensive transit projects such as light rail, monorail, or rapid transit systems are inherently difficult to develop and deliver as they rely on strong public support and availability of public funds. In recent years, urban environment problems and issues such as traffic congestion, shortage of affordable housing, and air pollution resulted in transit systems being an attractive transportation alternative to passenger vehicles. Indeed, the public, or at least a majority of people in large metropolitan areas see a value of having an efficient system to move a large number of people over long distances in a short period of time (Baum-Snow and Kahn, 2000). However, while the support of the public for such systems grew, the capability of the public sector to fund and finance infrastructure projects including transit projects has declined.

To bridge this gap, the private sector has started to deliver and operate needed infrastructure through contractual instruments with the public sector often referred as Public-Private Partnerships (PPPs). The key factor in structuring such deals is risk allocation scheme in which risks are allocated to the contractual parties. In these settings, the private sector is often unwilling to accept the revenue risk or the system ridership risk. This situation brings the public sector to a point where a decision to proceed with taking on the ridership (revenue) risk has to be made. With the current lack of needed funds to support many fundamental responsibilities of the public sector such as education, health, and others, this decision becomes ever more difficult.

However, following the completion of a transit system the value of surrounding real estate increases as transit access is a highly valuable feature (Laakso, 1992; Strand and Vagnes, 2001; Hess and Almeida, 2007; Debrezion et al., 2007; Geotz et al., 2009). In fact, this represents a positive externality which not only brings an increase in property value for the owners in the affected areas, but also results in an increase in property tax revenue for the public sector. Financing infrastructure utilizing future revenue resulting from appreciation in the property value is known as Tax Increment Financing (TIF). This allows municipalities to designate an area in proximity of a newly built transit system, and then collect the increased property tax revenues from the appreciation of property in that area. Therefore, an option (contingent claim) could be designed by the public sector that will provide a part of this "almost certain value" from the tax increment revenue to the private sector, acting as a risk mitigation tool in project development as it offsets some of the uncertainty in future revenue: uncertain ridership revenue plus certain tax increment revenue can provide a risk profile that private sector would be willing to take.

The objective of this paper is to develop a method for designing and valuating an externality-based option (contingent claim) for transit projects. The paper presents an auction-generated price model that captures dynamic changes in real estate prices and the impact of a new transit system on the property value. The remainder of the paper is organized as follows. In the next section, background and literature on real estate price models are discussed. Model formulation is presented in the third section. The case study and discussion are presented, followed by the implications to practitioners in the fourth section. Finally, in the fifth section major findings and conclusion are discussed.

2. BACKGROUND AND LITERATURE REVIEW

2.1 Section summary

This section presents the literature review on tax increment financing (TIF) and real estate valuation or property price estimation. Based on a certain designated area around an improvement project, tax revenue of the current (increased) value of properties in the designated area affected by the improvement project can be collected during the a fixed period of time to pay for the expenditures of the project or finance itself. The comparable method, multiple regression, hedonic pricing, artificial neural networks, spatial analysis, autoregressive integrated moving average model, stochastic process method, microeconomics equilibrium approach were used to valuate real estate or estimate prices of properties. This paper in section 3 and section 4 proposes an auction-generated price model to simulate the prices of the properties for taxation purpose and utilize the tax increment financing tool to calculate the total increased tax revenue based on appreciation of properties generated by the proposed auction-generated price model.

2.2 Tax increment financing (TIF)

Tax increment financing (TIF), first introduced in California in 1951, allows a municipality to designate an area for improvement, and then earmark future growth in property tax revenues to pay for economic development expenditures for a fixed period of time (Dye and Sundberg, 1998). By 1989, TIF had been authorized for use by local governments as a part of their economic development incentive packages in over 30 states and this financing mechanism represented one component of increased state and local initiative in economic development, and illustrated the increasing cooperation between the public and private sectors in this policy area. Under tax increment financing plans, property taxes were still collected on the property, but the taxing authorities collected on an "original assessed value" or base year (the value prior to development), to determine the assessment. Any increases in property values and assessment would determine a "current assessed value" of the property. The difference between the current and original assessed values was the "captured assessed value" which was retained by the TIF authority to pay for development costs or to repay loans. (Klemanski, 1989) TIF became increasingly popular as a means of both promoting redevelopment of blighted areas and attempting to attract private investment in the 1970s and 1980s (Klemanski, 1990; Donaphy *et al*., 1999). Klemanski (1989) stated that this "pay as you go" approach had been popular since many local governments had faced budgetary and political pressures which had opposed borrowing and the disadvantage of this approach rested on that the captured increments had to be accumulated over many years before they became large enough to finance a project. TIF is now used in 49 states and the District of Columbia (Weber and Goddeeris, 2007). The improvement typically leads to appreciation of properties in the affected area (TIF zone), simultaneously generating higher tax revenue for the public sector. TIF relies on the unusual feature of the local public finance in the US, that is, taxation of the same property-tax base by numerous overlapping jurisdictions (Brueckner, 2001). Dye and Sundberg (1998) found that much of the literature in TIF was in the field of planning or applied economic development, while Anderson (1990) found a positive relationship between property value growth and TIF. Naccarato (2007) generally summarized the steps that TIF worked through: (1) a geographic area was designated (the TIF district); (2) a plan for specific improvements in the TIF district was developed; (3) bonds were

issued and the proceeds were used to pay for the planned improvements; (4) the improvements encouraged private development and thus raised property values above where they would have been without the improvement; (5) with higher values, property tax revenues rose; (6) property tax revenue from increased assessments over and above the level before the TIF project began (the tax increment) was used to finance the debt.

TIF offers municipalities an innovative opportunity to collaborate with private sector in achieving public objectives (Ewoh, 2007). Taxes on the original assessed valuation of the properties are allocated to taxing bodies with jurisdiction over area properties, while incremental taxes from increase in property values are used to reimburse developers. Such increased tax revenue distributed to private sector could help private sector to pay off the expenditures on public infrastructure investment. Donaghy *et al.* (1999), after Kim *et al.* (1985) described in general terms how TIF operated and how its success as an economic development instrument depended on rates of growth in property values in the presence and absence of TIF districting, introduced a general model of tax increment financed redevelopment and used the model to illustrate how expenditures on public infrastructure and housing could induce private capital investment and growth in property values and to frame the problem of how to best manage a TIF fund to realize development goals. Orrick (2006) argued that TIF districts could be a win/win/win situation for the local jurisdiction, the developer, and the ultimate owners of the benefited development in that local jurisdiction gained properties with increased value which would ultimately result in an increased tax revenue and which in the meantime might generate additional sources of other tax revenues and developer of properties could reduce development cost. Naccarato (2007) analyzed the value of TIF to local governments and considered that TIF offered "self-financing" for development projects, allowing local governments to encourage development and also local governments had found TIF to be especially useful in funding infrastructure improvements needed to attract development that could be either commercial or residential. Brueckner (2001) pointed out that TIF was not always viable as a financing method because it might not generate enough additional revenue and showed that TIF's viability was ensured only when the public good was at least moderately underprovided relative to the socially optimal level. Sullivan *et al.* (2002) presented a detailed review of steps required to implement TIF projects in Texas and developed a comprehensive framework to guide policy makers in evaluating prospective TIF projects. Smith (2006) suggested that properties located within a designated TIF district exhibited higher rates of appreciation after the area was designated a qualifying TIF district when compared to those properties selling outside TIF districts and when compared to properties that sell within TIF district boundaries prior to designation. Weber *et al.* (2007) summarized that empirical studies had demonstrated a positive relationship between infrastructures (primarily transportation-related), local business growth, and housing prices.

2.3 Real estate valuation review

Value of the properties surrounding the transit system varies during the TIF period. Hence, it is important to develop a valuation model that can capture dynamics of price changes over time. The literature in real estate valuation includes modeling approaches such as comparable method, multiple regression, hedonic pricing, artificial neural networks (ANN), spatial analysis, autoregressive integrated moving average model, stochastic process method, microeconomics equilibrium approach, and others.

The sales comparison approach is a traditional property valuation method (Pagourtzi et al., 2003). It assumes that the property has the close appraisal to the sales prices of a similar property located in the same market area. The comparable method is highly dependent on the transaction data's availability, accuracy, completeness and timeliness. Regression analysis has been widely used in real estate valuation and appraisal (Wilhelmsson, 2002). The most used methods for valuation of real estate are hedonic pricing model and multiple regression model. Property value is a function of locational, physical, legal and economic factors (Wyatt, 1996). Britton *et al.* (1989) regarded the following factors as value significant: location, physical state, tenure, purpose of the valuation, time (especially relevant in a volatile market) and planning. Four main elements noted by RICS (1992) are time, location, physical characteristics and the conditions of sale. Wolverton (1997) conducted multiple regression analysis using characteristic variables of real estate. Hedonic price models recognize the complexity and heterogeneity of property and represent a relationship between the price of property and its attributes (Mok *et al*., 1995).Case and Quigley (1991) not only mentioned that the hedonic techniques had been used widely, but also represented a simple regression model which also included variable of time for generating the selling price of property. Benjamin *et al.* (2004) introduced the basics of real estate appraisal and multiple regression analysis, in particular, real estate valuation for mass property tax assessment.

However, both the comparison method and regression model faced the criticism for the subjective judgment and inaccuracy, as well as for the problem of multicollinearity and nonlinearity (Worzala et al., 1995). Thus, artificial neural networks (ANN) have been proposed as a solution. An ANN model must firstly be trained from a set of data and then the model is utilized to estimate the prices of new properties from the same market. ANNs use variables such as the ones in multiple regression analysis. The typical topology of ANN included input layer, hidden layer and output layer. Worzala *et al.* (1995) applied neural networks to real estate appraisal and estimation of the sales price of residential properties, while Rossini (1998) applied ANN to residential property valuation. Worzala *et al.* (1995) suggested that the ANN method was inadequate as it was only slightly better than multiple regression model and not easy to use.

Geographical representation of properties and its value have increased since GIS was introduced. In GIS settings, value maps show spatial distribution of property values. Such maps are often used for property taxation purposes. In Denmark, the public can check their property tax assessments by viewing the value map. The database of geographical property information system can be structured by grouping the data as follows: (1) Address and location; (2) Use, type and description of the property; (3) Planning information (easements and restrictions); (4) Value for taxation purposes; (5) Physical description (floor space, floor layouts, rooms, external areas, car parking, and type of construction; (6) Legal data (summary of any tenancies, transaction data). While GIS can improve the measurement of location, the spatial techniques use a set of data based on discrete points for sub-areas, then determine a function that will best represent the whole surface which can then be used to predict values at other points or sub-area. Within GIS framework the use of surface response analysis techniques provides a three-dimensional visualization of the value of location. Spatial pattern analysis can help detect additional neighborhood factors that must be considered to explain market variability (Pagourtzi et al., 2003). Wyatt (1996) demonstrated that the spatial analysis of property data enhanced the valuer's understanding of locational influences on property value. Wyatt (1997) developed a GIS-based property valuation database for a study about geographical representation of property information

at the individual property level while value maps were constructed to illustrate the geographical spread of property values.

However, to valuate contingent claim depending on property value it is essential to model the dynamics of price change. For example, autoregressive integrated moving average (ARIMA) model, based on autoregressive (AR) model and moving average (MA) model with time series model, can reveal nonstationary behavior of series (Pagourtzi et al., 2003). Tse (1997) studied Hong Kong's real estate prices using ARIMA model. The study results showed how the office and industrial property prices in Hong Kong could be fitted into the ARIMA equation. From the perspective of real estate development, real options are valuable while there are highly unpredictable and volatile markets in the future, thus real options models have been prevailingly applied into the study of real estate pricing. Yamazaki (2001) developed a basic real option pricing model of land prices on the demand side in central Tokyo and verified that the option-based investment models could better explain the pricing of land markets in Japan. The value of the underlying asset (i.e. the land, the building, and housing) was assumed to follow a geometric Brownian motion (GBM) stochastic process with a constant drift and a known variance (Williams, 1991; Quigg, 1993; Capozza and Sick, 1994; Grenadier, 1996). Sing (2001) further showed that GBM process could be a viable approach to model land value. Capozza and Sick (1994) developed a model for simulating urban and agricultural land prices, assuming the normal process, while Hilliard *et al.* (1998) assumed that housing prices followed the lognormal process. However, Kawaguchi and Tsubokawa (2001) claimed that the price of real estate neither followed a normal nor log-normal process. They developed a real option pricing model without assuming "Ito Process" and allowed the price processes to have serial correlation properties while traditional continuous real options model requires the process to have the structure of the "Ito Process" in order to obtain stochastic differential equations (stochastic integral representation) as Kawaguchi and Tsubokawa (2001) mentioned. The model presented in their study used discrete time diffusion process to develop real estate price dynamics.

Dynamic equilibrium model with auctions represents a microeconomics approach to model property value. Anas and Arnott (1989) developed a discrete-time, nonstationary dynamic equilibrium model of the housing market considering both consumer and investor's activities. They stated that the competition between households for the dwellings generated temporary equilibrium rent, developed the behavior of investors, derived the asset bid price equations and then offered the conditions the housing market must satisfy for the dynamic equilibrium. Martinez and Hurtubia (2006) presented a dynamic equilibrium model for the real estate market which permitted the existence of a transient surplus in supply and demand of real estate. The prices were resolved through an equilibrium mechanism in each time period which adjusted demand to the supply generated from previous periods. The prices fully changed because of excess of demand or excess of supply. Here, the auction mechanism played an important role in the formation of prices.

Auctions have grown in importance as a way of trading in a wide range of goods including real estate (Azasu, 2006). As stated by Good and Hammond (2006), auctions are being used regularly in several areas of the world to sell residential real property and the result of their study indicated that auctions could be an effective way to market and sell residential properties. The literature has a widespread study on auction theory and real estate auctions. Followings are some related studies with price formation or factors affecting price or bids in auction. Wilson (1977) demonstrated that the price formation via the procedure of competitive bidding satisfied a

version of the law of large numbers, in both the probabilistic sense and the economic sense and with certain regularity conditions satisfied, the sale price converged almost to the "true value" as the number of bidders increases even though each bidder observed only incomplete sample information about the value. Ong *et al.* (2005) found that the significant variables in explaining the probability of a successful auction included the state of the market, the timing of the auction (year), the potential number of bidders and certain auctioning house using data from Singapore on auctions of residential property from 1995 to 2000. Azasu (2006) pointed out that the optimal behavior of each bidder leads to each offering to buy at a price equal to their bids. Ooi *et al.* (2006) showed that expected sales price increased with the number of bidders both because each bidder had an incentive to offer a higher price and because of a greater likelihood that a high-value bidder was present.

In fact, real estate auctions are an increasingly popular method for selling residential and commercial properties in that the auctions have become an appropriate selling strategy of timely disposition and also obtaining fair prices (Quan, 1994). Auction-generated prices could capture the characteristics underlying in the interaction between demand and supply. This paper proposes an auction-generated price model to simulate the prices of the properties surrounding the new transit system for taxation purpose and then presents the derived value of externality-based option (contingent claim) to the private sector. Such an approach allows to capture supply-demand dynamics in property valuation and consideration of effects such as proximity of transit station on demand. It is important to note that the paper is not intended to prove whether TIF is viable or not, but rather present a method to value externality-based options as an internalization tool for positive externalities generated by a new transit system.

3. MODEL FORMULATION

3.1 Section summary

As proposed in section 1, an option (contingent claim) could be designed and offered by the public sector that will provide tax increment revenue to the private sector acting as a risk mitigation tool because it offsets some of the uncertainty in future revenue of infrastructure project. The designed contingent claim and its fundamental definition are discussed in this section. In order to value the externality-based option (contingent claim), an auction-generated price model is used to determine the added value between the base price and the current price of the affected properties after a new transit system is introduced. The basic concepts in auction mechanism are introduced in this section. The variables in the auction-generated price model are the feasible number of bidders and upper limit of maximum willingness to pay from bidders as the pricing model determines. Figure 1 introduces the overall process for this study. Detailed explanations are provided in the following sections.

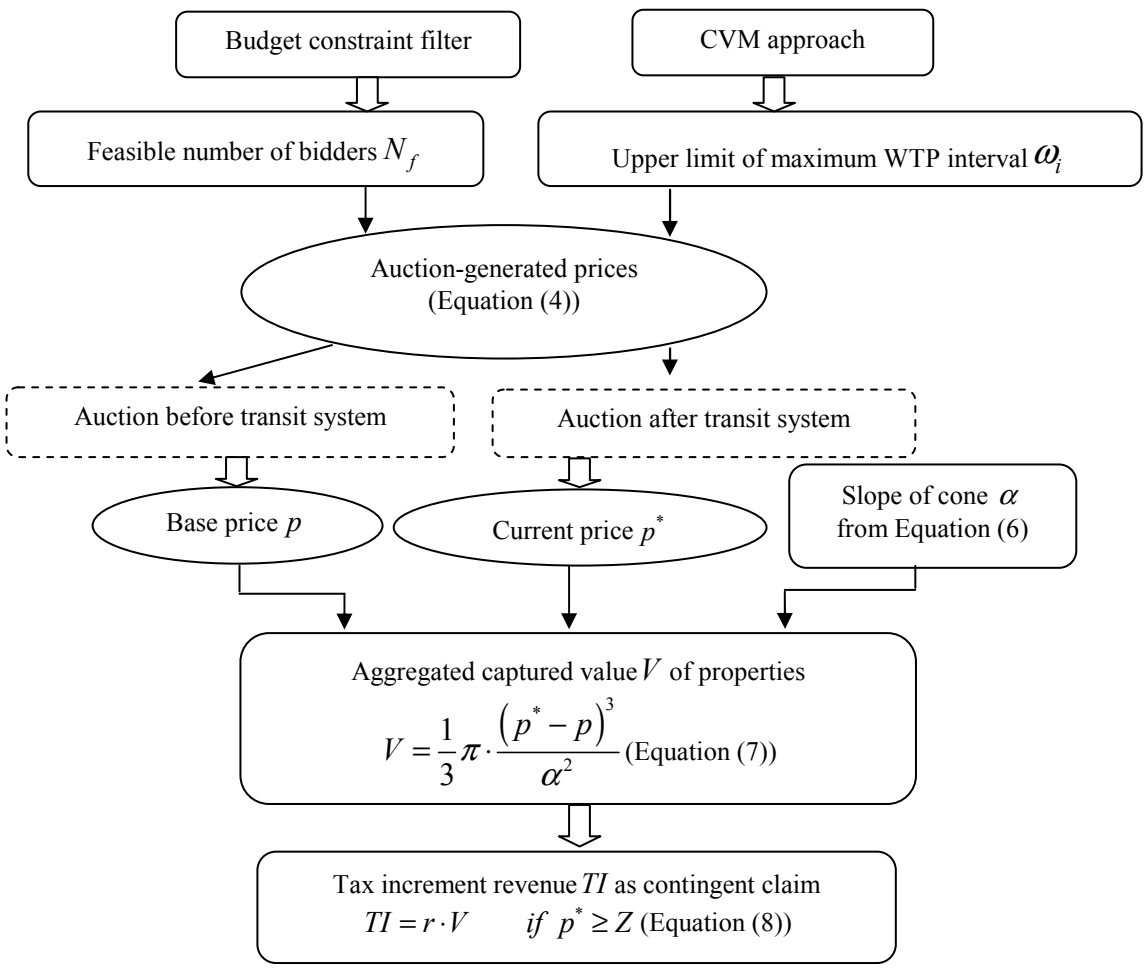

Figure 1 Overall process for externality-based option (contingent claim) model and its validation

3.2 Auction Assumptions and Auction-generated real estate prices

McAfee and McMillan (1987) classify sales actions in four basic types: English auction, the first-price sealed-bid auction, the second-price auction and the Dutch auction. This paper is discussed mainly based on first-price sealed-bid auction. The first-price sealed bid auction is a simultaneous-move auction in which bidders simultaneously submit concealed bids. Then, the auctioneer awards the item to the highest bidder who pays the bid amount (2006).

Single object first-price sealed-bid auction is used to generate the expected revenue (selling price) to the seller. According to Krishna (2002), the assumptions of the private value auction are as follows. Risk neutral bidder i assigns a value of X_i to the object where X_i is the maximum amount a bidder is willing to pay for the object. Each X_i is independently and identically distributed on the interval $[0,\omega]$ according to the increasing distribution function F which admits a continuous density f and has full support. Suppose that the bid 1 is fixed, let the random variable $Y_1 \equiv Y_1^{(N-1)}$ denote the highest value among the $N-1$ remaining bidders. Y_1 is the highest order statistic of $X_2, X_3, \cdots, X_N$. Let G denote the distribution function of Y_1, so for all y, $G(y) = F(y)^{N-1}$, and $g = G'$ is the density of Y_1. All components of the model other than the realized values are assumed to be common knowledge to all bidders. The number of bidders is common knowledge, while the distribution F is the same for all bidders. The latter implies that the bidders are symmetric. It is assumed that the bidders are not subject to any budget constraints, that is, each bidder i can both willing and able to pay the seller up to his or her value X_i, and the seller's reservation price is zero. Then, the expected payment of a particular bidder in the auction is as Equation 1 (Krishna, 2002):

$$E[R] = \int_0^{\omega} y\left(1 - F(y)\right) g(y)\, dy \tag{1}$$

The expected revenue or expected selling price to the seller is N times the expected payment of an individual bidder:

$$E[R] = N\int_0^{\omega} y\left(1 - F(y)\right) g(y)\, dy \tag{2}$$

Now consider that bidders have different levels of income and maximum willingness to pay (WTP) is defined as an interval $[0,\omega_i]$. Also, let the budget constraint be defined as that bidder's income should be greater than the initial price of real estate. This results in N_f bidders entering the auction (i.e., the bidders able to pay). Then the expected revenue or expected selling price to the seller is:

$$E[R] = \sum_{i=1}^{N_f} \int_0^{\omega_i} y\left(1 - F(y)\right) g(y)\, dy \tag{3}$$

where N_f is the feasible number of bidders. In a special case, if values are uniformly distributed on $[0,\omega_i]$ (uniformly distributed valuations is a typical assumption employed in the literature (Wolfstetter, 1996)), then the expected revenue is:

$$E[R]=\sum_{i=1}^{N_f}\int_0^{\omega_i} y\left(1-F(y)\right)g(y)\,dy=\frac{N_f-1}{N_f+1}\frac{\sum_{i=1}^{N_f}\omega_i}{N_f} \tag{4}$$

The derived expected revenue shown in Equation 4 is not only dependent on the feasible number of bidders but also the weighted average of ω_i (upper limit of maximum WTP interval) from all the feasible bidders. The generated expected revenue in period k will be the initial price for period $k+1$ as in Figure 1 below.

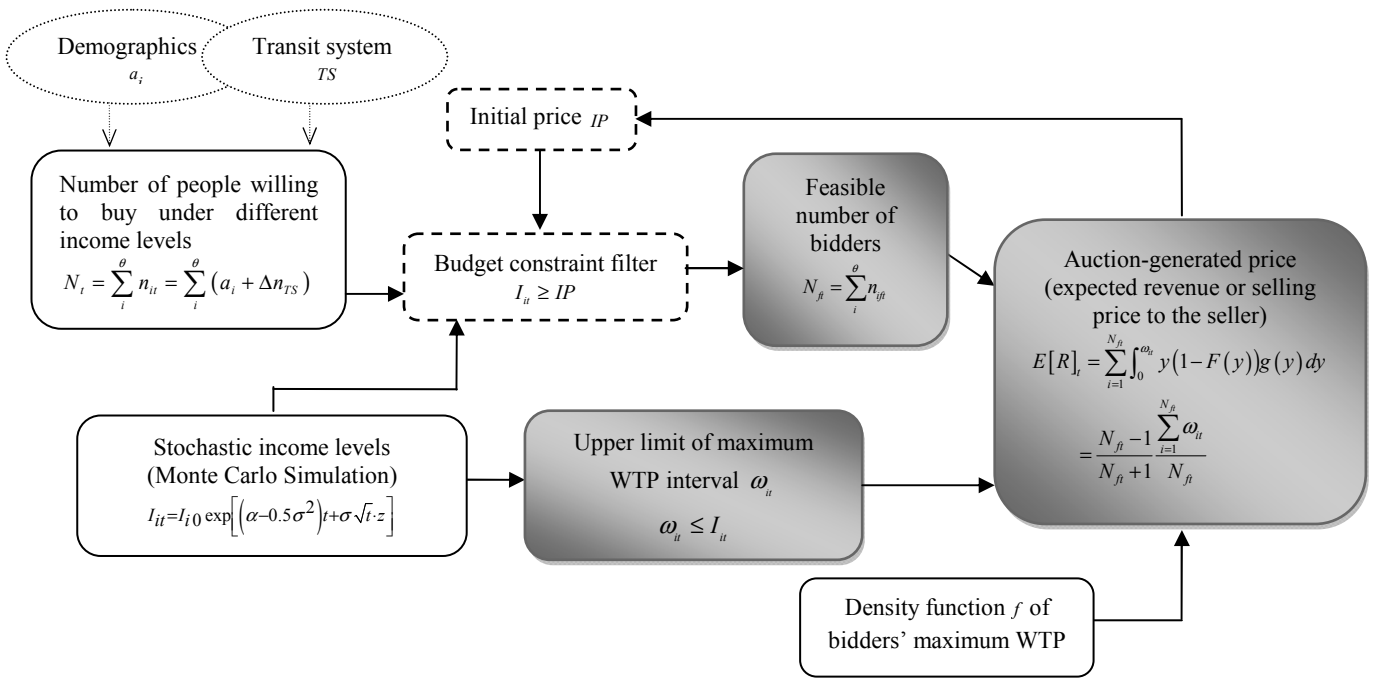

Figure 2 Dynamic prices of real estate generated from auction

Figure 2 illustrates the framework for modeling price dynamics. The process begins from a supply side, where the initial price is determined by the producer based on his production cost and profit. The demand of consumers is viewed as exogenous variable which relies on factors such as population growth and others, but also on the attracted demand resulting from accessibility to the transportation system (i.e., newly built transit system). In submitting bids, the consumers are assumed to optimize their maximum WTP for a certain type of real estate given that the maximum WTP is less than the available income. Hence, the feasible number of bidders $N_f(IP,TS,I)$ is influenced by the initial price (IP), the income of the bidders I, as well as the access to the newly transit system TS. In other words, the transit system is able to attract a greater number of bidders once it is available to public.

In order to simulate the actual real estate market, it is assumed that the sequential first-price auctions are processed for each type of real estate. More specifically, each type of real estate or a perfect substitute (property having the same characteristics and the same level of price even though they may be located at different locations) has a corresponding sequential auction in

which the objects are sold one at a time in separate auctions; that is, the bids in the auction for one of the objects do not directly influence the outcome of the auction for another. It is assumed that a particular bidder has not already won an object and so is still active in the k th auction. Further, it is demonstrated by Krishna (2002) that the expected price in the $k+1$th auction is the same as the realized price in the k th auction in the sequential auctions.

The real estate price considering all types of properties sold in sequential auctions would be the weighted average price of all the sold properties:

$$P^t = \frac{\sum_i Q_i^t \cdot p_i^t}{\sum_i Q_i^t} \tag{5}$$

where P^t is the overall weighted average real estate price at time period t; p_i^t is the price of a certain type i real estate generated from the auction which is the expected revenue $E[R]$ in Equation 4 at time period t; Q_i^t is the number of total sold properties of type i in that particular sequential auction.

3.3 WTP and Contingent Valuation

The maximum WTP for the properties in the affected areas is an unknown parameter in the auction-generated price model proposed in Figure 2. To determine the value of this parameter contingent valuation method (CVM) has been commonly used. This non-market valuation method measures the value of changes in the provision of public goods and provides estimates of WTP via designing survey or questionnaire (Painter *et al.,* 2002). "Contingent" means that respondents are asked how they would act if they were placed in certain situations (Samdin, 2008). The bidders' maximum WTP, before as well as after the introduction of a transit system can be assessed using survey.

3.4 Contingent claim model

A contingent claim is an asset whose payoff depends on the value of another "underlying" asset, the value of which is exogenously determined: a valuation relationship is a formula relating the value of the contingent claim to the value of the underlying asset and other exogenous parameters (Brennan, 1979). As proposed in this study, the contingent claim of externality-based option here depends on the uncertain value of prices of real estate and other parameters, such as, tax rate. The process to calculate the contingent claim proposed in this study is discussed as following with more details.

The newly built transit system impacts the auction-generated prices of properties for each time period due to the attracted demand for the access to the transportation. Let's assume that rail station of the transit system is built at location O as in Figure 3. Then, for modeling purposes, the TIF zone could be determined as a circular area with a center at O and a radius of R.

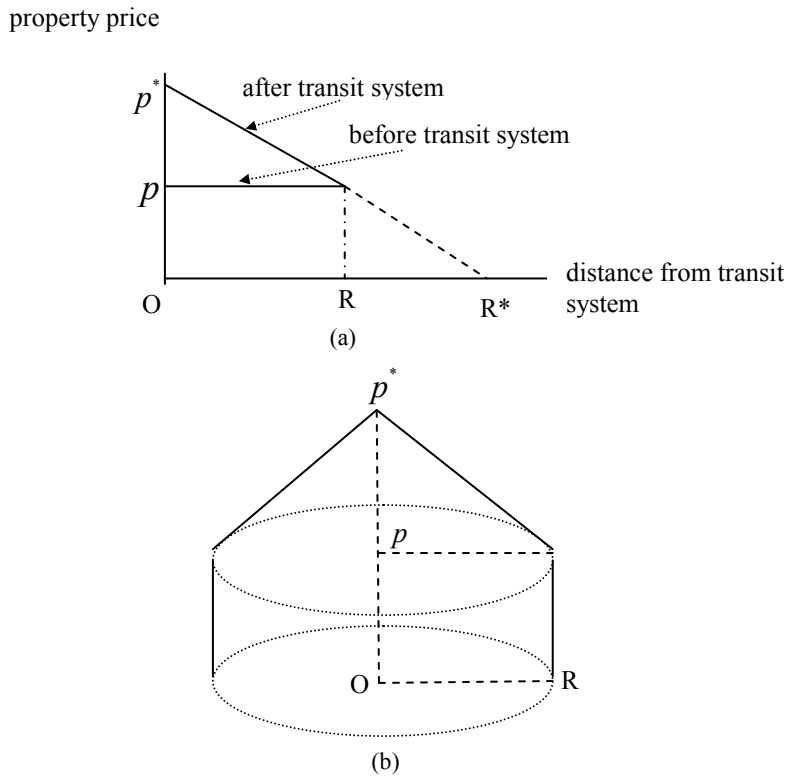

Figure 3 Property prices and price-increased area before and after access to transit station

Assume that proximity to station is the only factor considered for property valuation and the value of property decreases as the proximity to station increases. As shown in Figure 3, without the provision of transit station, the values of properties in the circle area are the same as p. When transit system is introduced and private investment is attracted to the TIF zone, the property value is expected to rise, especially for the first few years of the TIF district's life (Weber and Goddeeris, 2007). Let the price of property at the station increase from a base assessed value of properties p to a current value p^*. Also, let this value linearly decrease to 0 at the point with a distance of R^* from the station in Figure 3-(a). The intersection of two price lines before and after the introduction of transit station determines the radius R of the affected area, while the intersection represents the boundary where the value of properties does not change. The aggregated captured (increased) value in the affected circle area is the volume of the cone shown in Figure 3-(b) based on the affected base area πR^2 and height $\left(p^* - p\right)$. The slope of this cone could be determined by the coefficient α of the regression model (Coffman and Gregson, 1998):

$$p^* = \beta_0 + \alpha \cdot \frac{1}{R^*} + \beta_i \cdot X + \varepsilon \qquad (6)$$

where Xs are the other factors influencing the value of properties in the regression. The regression coefficient α is the slope of the value-distance gradient $p^* R^*$ (the reduction in value for each increment in distance from transit station). The excess value V of the TIF district, that is, the aggregated captured value (the difference between new increased value and base value) of properties in the affected area, is the volume of the cone shown in Figure 3-(b) and Equation 7:

$$
\begin{aligned}
V &= \frac{1}{3}\pi R^2 \left(p^* - p\right) \\
&= \frac{1}{3}\pi \cdot \left(\frac{p^* - p}{\alpha}\right)^2 \cdot \left(p^* - p\right) \\
&= \frac{1}{3}\pi \cdot \frac{\left(p^* - p\right)^3}{\alpha^2}
\end{aligned}
\tag{7}
$$

Hence, the public sector could define and offer an option to the private sector where all properties with a current price above a pre-determined price level Z should be taxed and this tax increment income is internalized by the private sector (e.g., transferred to the private sector). The value of this tax increment TI at rate r is:

$$TI = r \cdot V \qquad if\ p^* \geq Z \tag{8}$$

In summary, based on the realized aggregated captured value of properties in the affected area of TIF using auction-generated price model, the externality-based option (contingent claim) could be provided to private sector by public sector so that private sector could choose to get the "almost certain" tax increment revenue once the current value of properties passes a pre-determined price level.

4. CASE STUDY AND DISCUSSION

4.1 Section summary

A case study is conducted in this section considering a hypothetical transit system (monorail) project and 7 parcels in the TIF zone. Single-object first-price sealed-bid auction is used to generate the dynamic prices of the real estate for each station-affected area to model the impact due to newly available transit system. Parameters and value of variables are assumed, such as, initial price of properties surrounding the station, maximum income of bidders, number of bidders willing to buy, and slope of the value-distance gradient. The results of the auction-generated dynamic prices for stations are summarized. Aggregated captured value of properties affected by the new transit system and tax increment revenue which is the value of contingent claim is then calculated.

4.2 Case study

Consider a hypothetical transit system (monorail) project in Austin, Texas. Assume there are 7 stations (Station A to G) along the red line with the affected circular areas, that is, assume that there are 7 parcels in the TIF zone. Suppose the impacted circles do not overlap with each other. Also, assume that the impacted circle radius changes over time because the price difference $\left(p^{*}-p\right)$ changes over time, but the slope of the value-distance gradient (the reduction in value for each increment in distance from rail station) remains constant.

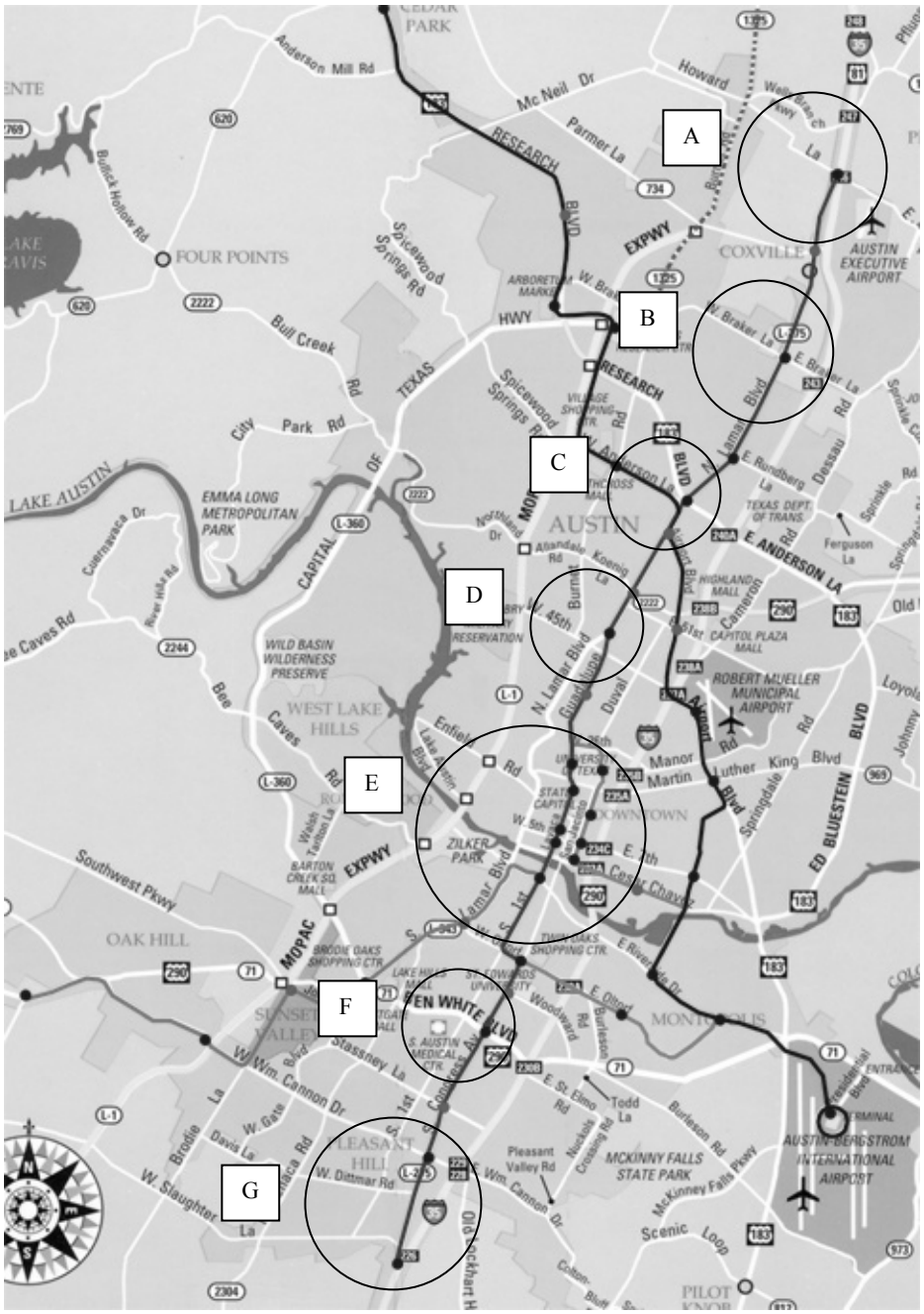

Figure 4 Monorail-red line at Austin with stations effect

Since in sequential auctions the expected price in the $k+1$th auction is the same as the realized price in the kth auction, single-object first-price sealed-bid auction could be used to generate the dynamic prices of the real estate for each station-affected area to model the impact due to newly available transit system. With the already known initial price for the property surrounding each station, assume that in each auction there are θ groups of households with different income levels willing to bid whose valuations are uniformly distributed on $[0, \omega_i]$. Before this new transit system is built, suppose there is $a_i = 1$ buyer under each income level,

thus totally $N = \sum_{i}^{\theta} n_i = \sum_{i}^{\theta} a_i$ buyers willing to buy that property. Assume that starting from the highest income level, each initial income level decreases 5 from last higher level and the income sequence follows stochastic process with mean drift $\alpha = 0.001$ and volatility $\sigma = 0.025$. The assumed numbers for mean drift and volatility of income are intended to simulate incomes that do not fluctuate too much because the number of buyers is assumed to be small. As shown in Figure 2, the income level works as a budget constraint, filtering number of bidders in the auction. As previously mentioned, the real exact maximum WTP could be obtained by CVM through surveys, but not attainable in this study, thus just for illustration purpose, the upper limit of maximum WTP interval ω_i in Equation 4 is assumed to be a weighted sum of the initial price and maximum income with factor 0.2 for initial price and factor 0.8 for maximum income since people's WTP is related with their incomes, the initial price of real estate and other factors as well. Finally, people who can afford this initial price would enter into the auction and bid for that property, and the feasible number of bidders N_f under all different level incomes could be obtained via budget constraint filter as shown in Figure 2.

Now, let the newly built transit system, shown in Figure 4, be introduced at period 6. Thus, the number of bidders willing to buy would increase by Δn_{TS} under each different income level for each following period. If 15 time periods are considered for TIF contract as a case example, the value of properties increases due to the impact of the transit station during period 6 to 15. It is assumed that the initial price in downtown area is the highest (for example, $IP = 140$ for station E in Table 1), people coming to auction for downtown area have higher level of income (for example, $Maximum\ Income = 190$ for station E in Table 1), the number of attracted bidders increases greater for less dense area than downtown area after the introduction of transit system (for example, $\Delta n_{TS} = 6$ for station A, and Δn_{TS} increases more for station further from station E) based on the fact that property values in the least dense areas of a city tend to grow faster than in more mature neighborhoods (Byrne, 2006) and the slope α of the value-distance gradients is smaller for downtown station than the other ones, that is, the reduction in value for each increment in distance from transit station is the smallest for downtown station. Table 1 shows the assumed parameters.

Table 1 Assumed Parameters and Estimation Results for Transit System

Station	*IP* ($)	Maximum Income ($)	Δn_{TS}	α (slope)	Aggregated increased value *V* ($)			Tax increment *TI* ($)		
					S1	S2	S3	S1	S2	S3
A	90	140	6	0.38	1464877	1608979	1575760	146488	160898	157576
B	100	150	5	0.438	1150577	1116520	1102302	115058	111652	110230
C	110	160	4	0.44	1027120	932563	901464	102712	93256	90146
D	120	170	4	0.45	847288	731042	906296	84729	73104	90630
E	140	190	1	0.40	0	0	0	0	0	0
F	120	170	4	0.46	734651	1077623	963192	73465	107762	96319
G	110	160	5	0.445	1280076	1313171	1274929	128008	131317	127493
Total					6504588	6779897	6723944	650459	677990	672394

The results of the auction-generated dynamic prices for station A are summarized in Table 2. By considering three different simulated income paths (S1, S2 and S3) the original and new auction-generated real estate prices for station A are shown as Figure 5.

Table 2 Auction-generated Current (New) Prices p^*

Period	IP	Max income	N_f	Average WTP	Average income	p^*
1	90.00	140.00	11	110.00	115.00	91.67
2	91.67	143.84	11	112.86	118.15	94.05
3	94.05	140.32	10	113.02	117.77	92.47
4	92.47	146.73	11	114.92	120.53	95.76
5	95.76	132.60	8	111.97	116.02	87.09
6	87.09	141.88	77	110.66	116.55	107.82
7	107.82	145.77	56	123.60	127.55	119.27
8	119.27	138.82	28	128.96	131.39	120.07
9	120.07	141.70	35	129.27	131.57	122.09
10	122.09	132.03	21	126.27	127.32	114.79
11	114.79	141.81	42	126.28	129.15	120.41
12	120.41	137.80	28	128.41	130.42	119.56
13	119.56	139.13	28	129.25	131.67	120.34
14	120.34	136.17	28	127.16	128.87	118.39
15	118.39	144.83	42	129.20	131.90	123.19

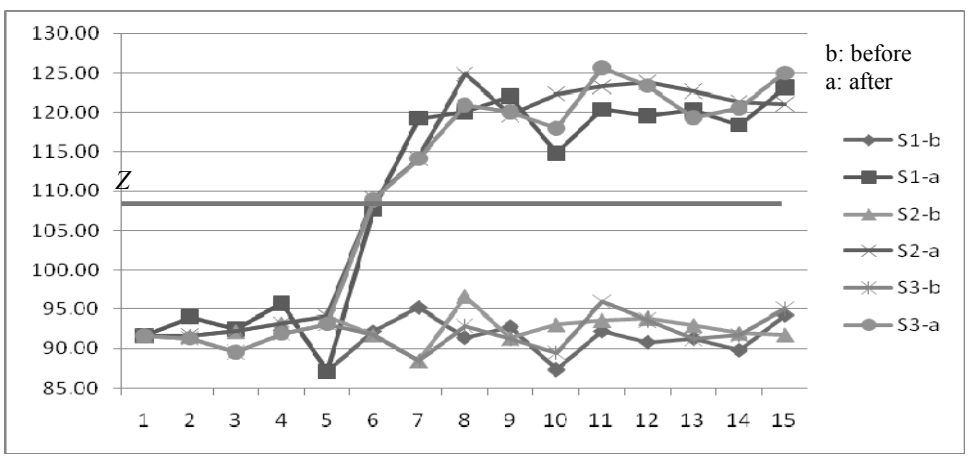

Figure 5 Base price p and current price p^* for station A

As observed from Figure 5, auction selling prices show a dynamic change and a sudden jump (but it is not the highest in the whole TIF life in this case study, for example, for station A the first summit price comes in period 8 or 9) when the number of bidders largely increases due to introduction of a transit station. The larger number of bidders, the higher price the auction generates as the initial price for the next period. This works as a constraint to reduce the feasible

number of bidders for next time period and consequently comes with an inverse lower selling price. Overall, the model generates prices that keep rising on average for the first few years of the TIF district's life. This trend is then followed by the dynamic fluctuations due to the characteristics of demand and supply.

Assume the pre-determined price Z in the option is 20% higher than the initial price, that is $Z = p \cdot (1 + 20\%)$, then if the current price of property increases across the pre-determined price line, the captured value of properties would be taxed for a rate of $r = 10\%$ otherwise no tax. Aggregated captured values V and tax increment TI calculated using Equation 7 and Equation 8 separately are shown as Table 1. The average tax increment collected from the aggregated captured value of properties regarding three different paths is $666,948 which would be offered to private sector as a contingent claim.

4.3 Implications to Practitioners

This paper shows that the capital gain of the tax revenue from the appreciation of property value might be substantial. Two important implications should be considered to practitioners. First, the public sectors (transportation agencies) should be aware that they could enhance financial support from private sector for project development by offering this externality-based option. This option acts as a risk reduction instrument which in turn may reduce the uncertainty in future project value. Second, the private sectors should be aware that this "almost certain value" may not be that absolutely certain. The current real estate environment is a reminder that there are multiple factors affecting the prices of real estate, not only transit. These factors could be dominating the price formation.

5. SUMMARY AND CONCLUSIONS

This paper proposed that an externality-based option (contingent claim) could be designed and offered by public sector to the private sector in order to offset the risk that there is uncertainty in the future revenue of the transit system. The paper demonstrates that the externality-based option can provide value to the private sector developers since the new transit system would attract more demand and may increase property value in the affected area. The first-price sealed-bid auction is used to analyze the bidding and price-generated process with people having different budget constraints. Further, the proposed auction-generated price model is capable of capturing key supply demand characteristics of the market in valuation process. The auction-generated price is not only dependent on the feasible number of bidders, but also the average weighted upper limit of bidders' maximum WTP interval.

While the developed model captures the key factors in valuation of externality-based options, it is by no means perfect. Some of the parameters assumed in the case study are not based on real data, such as the bidders' maximum WTP, however, as the paper mentioned, it could be attained through surveys. As a whole, the proposed externality-based option in this study could assist public sector in collaborating with private sectors to invest transit system projects.

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