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Abstract Approved:

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As the traffic demand increases at a faster rate than the upgrade and maintenance of transportation facilities through the traditional public financing methods in the United States, the Public-Private Partnership (PPP) is becoming an important supplement to the public transportation infrastructure investment. There are already several existing PPP toll road projects in the United States that provide examples of practical experiences and lessons for launching future PPP toll road projects. Additionally, research in the past three decades has made significant progress in relevant research fields about PPP toll roads, for instance, toll regulation, private revenue restriction, and risk allocation. However, it is still difficult to apply these academic models and research results into practical projects. Therefore, one of the objectives of this thesis is to point out the gap between the analytical research results and practical needs, through reviewing systemically the current PPP toll road projects in the United States and the theoretical research. Potential research interests to focus on how to narrow those gaps between the theoretical research and practical projects' needs by

improving the models or releasing the assumptions, to make the analytical research results helpful to those decision-makers when facing a new PPP toll road project.

In addition, the paper simulates the Chicago Skyway, which is the first long-term leased toll road in the U.S., in order to predict the future travel and welfare impacts caused by the PPP toll road. Moreover, a “non-compete” clause experiment is designed and the codes of programming is done in this paper. Future studies can use the experiment and programming to test the effects of the “non-compete” clause to PPP toll roads.

The Review of PPP Toll Roads in the US and the Simulation of the Chicago Skyway

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Wei Xu, Author

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1. Introduction

The role of the private sector in transportation dates back to the beginning of road construction in the United States. The Long Island Motor Parkway (LIMP), the first American toll road designed specifically for motor vehicles, was privately sponsored [Vanderbilt, 2004]. This was followed an era of publicly financed road construction. Due to the continuously-growing traffic demand for travel and increasing challenges in investing highway infrastructure with traditional public capital, the Public-Private Partnership (PPP) has been playing an increasingly important role in toll road projects now. The public-private partnership toll road becomes an increasingly common project delivery mechanism which is used to finance highways in the U.S. The mechanism allows more and more private sector participation in transportation projects. There are often two main reasons: (i) Funding and (ii) Innovation and Efficiency.

<u>Funding Issue</u>

It is usually a big challenge to accumulate the necessary funding for a single project that solely depends on traditional highway finance. According to the Report of Federal Highway Administration's (FHWA) in 2002, federal, state, and local capital investment in the Nation's highway system in 2000 totaled $64.6 billion. However, based on automobile and truck vehicle miles traveled (VMT), the annual investment needed to maintain the asset value and expand the capacity of this tremendous resource was $75.9 billion [Poole & Samuel, 2006]. So even in a transportation system without any traffic demand growth, there is an $11.3 billion annual financial gap. Actually, with the increase of VMT in the United States, there is a need for more transportation facilities to be built to satisfy the traffic demand, not just maintenance work, which means that there is a much worse financial problem. According to the FHWA data from 1980 to 2000, the growth of VMT is much higher than the growth of lane miles of roadway in United Sates since 1985. To relieve the financial problem of traditional public highway funding, especially for large-scale highway projects, the private investment and PPP model are more likely to be implemented to supplement public funds.

Innovation and Efficiency

The private sector appears to be more willing to innovate, and more efficient in construction and operation than public agencies. Since the private firms take risks and need to make a profit from the project, they prefer to apply some innovation services and equipment to increase the toll revenue. For instance, the SR91 Express Lanes in Orange County (CA) relied on an electronic toll-collection system with a variable toll based on the time of day and the day of the week to achieve a smoother traffic flow after being taken over by a private company [Poole, 2000]. Another example is the Chicago Skyway - after being operated by concessionaire in less than four months, an electronic toll collection system was introduced on the Skyway. The city had considered implementing an electronic toll collection system on the Skyway for years but never did. Additionally, there are still some arguments about whether the private sector has higher private efficiency. Some people believe that the private sector has a higher efficiency than public agencies in road construction, but not in operation. We will discuss it further in section 2.

Based on these reasons, more and more states are enacting legislation allowing the public-private partnership transportation facility projects or transportation facilities privatization. Since 2001, private leasing projects have been implemented in at least seven states: Alabama, California, Illinois, Indiana, Michigan, Texas, and Virginia. New privatization initiatives have been officially proposed or were moving forward in at least sixteen states during 2007: Alaska, Colorado, Florida, Georgia, Illinois, Indiana, Missouri, New Jersey, Nevada, New York, Ohio, Oregon, Pennsylvania, Texas, Utah, and Virginia [Baxandall, 2007]. Between 1994 and early 2006, $21 billion was paid for 43 highway facilities in the United States using various "Public-Private Partnership" models [Deloitte Research, 2007].

Since the PPP is becoming a more and more popular trend in the United States practical road projects, many papers and reports are focused on it, especially about the regulation policies, private profit, and public welfare. People are quite interested to know who will be losers and who will be winners through those PPP projects. This paper will review most of the PPP toll roads projects in the US. Based on these studies, the policy or decision makers will get a better idea when facing proposals for a new PPP toll road project. This information will help them decide whether they should get involved in PPP projects. How do they set the toll rates to make profit? How do they allocate the risk of the projects? How do they regulate the private sector to retain the public welfare? Most of those questions are hot spots and focused by the studies and researches.

There are many papers, reports, and academic studies that review the some specific PPP toll road projects situations in the United States or globally. Unfortunately, few of them try to connect the academic studies and practical projects together. This paper reviews a large number of the current PPP toll roads projects in the United States, and also reviews and summarizes most of the papers and studies related to the those projects and PPP models, after 1990. By summarizing many current projects and related research, it will present a general idea to the readers what is the current situation of the US PPP toll roads and the states of associated academic studies. There are many previous studies and reports to summarize the PPP toll facilities in or outside the United States. Most of these studies either review some specific projects, or just focus on the academic research studies and models in PPP area separately. This paper tries to find the gap between the theoretical studies and the practical projects in the real world. By narrowing the gap, we can raise some critical suggestions to improve the existing PPP toll road projects in the United States, and give the decision-makers or policy-makers some estimation methods and references tools, based on the academic theoretical studies, for future projects. In addition to a review, a simulation of the Chicago metro area (12982 nodes, 35368 links) is used to test the future traffic and welfare impacts of a PPP toll road in the real world - the Chicago Skyway.

One of the hottest topics about the PPP toll roads is the “non-compete” clause in the road concession. The “non-compete” clause was first used in the SR 91’s concession, in which the public agencies were not allowed to construct any new roads nor improve any existing roads within a one-and-a-half-mile-wide corridor on either side of the toll lanes for the life of the agreement. Following that, there are several more PPP toll roads’ concessions including different forms of “non-compete” clauses. Obviously, the “non-compete” clause can protect the private revenue and mitigate the risk by limiting the capacity of the parallel public freeways and assuring the traffic in the toll road. It is a good way to increase the interest of the private sectors funding the toll road in order to address the public funding shortfall issue. However, the “non-compete” clause also lead to many problems.

First of all, the public freeway system near a toll road may suffer from congestion, but improvement or expansion is not permitted under the “non-compete” clause and this attracts many opposition opinions about the clause. Taking the SR 91 as an example, California Attorney General Bill Lockyer described the “non-compete” clause as a “polite form of highway robbery” [unbossed.com]. Second, the “non-compete” clause may attract more traffic demand on the PPP toll road whether the toll road can handle it or not. What will happen if the travel demand is more than the capacity of the toll road and the road suffers congestion because of the “non-compete” clause? Third, how to regulate the private toll rates based on higher traffic demand caused by the “non-compete” clauses is still a question. Few of the previous research studies focus on the impacts of the “non-compete” clause. This paper will discuss it and build an experiment to test the impacts of different types of “non-compete” clause for future study.

The plan of the paper is as follows. Section 2 reviews both the existing United States PPP toll road projects, including discussions about toll rates, financial mechanisms, and regulation methods of these projects, and the theoretical research and models about PPP toll road. Based on the review of both sides, Section 3 identifies the gap between the practical needs and the academic research about PPP toll road. Section 4 introduces the methodology of the Chicago Skyway simulation. The quantitative impacts analysis is given in Section 5. Section 6 designs an experiment to test the impacts of the “non-compete” clauses, followed by the conclusions and recommendations in Section 7.

2. Practice and Research Review of PPP Toll Roads in the U.S.

2.1. Practical Projects Level Review

In practice, there are several criteria to categorize the existing PPP toll roads all over the world. For instance, according to the FHWA website, the existing PPP tolls roads can be separated into several categories: Design-Bid-Build (DBB), Private Contract Fee Services, Design-Build (DB), Build-Operate-Transfer (BOT)/Design-Build-Operate-Maintain (DBOM), Lease-Develop-Operate (LDO)/ Lease Agreements, Design-Build-Finance-Operate (DBFO), Build-Own-Operate (BOO), and other Innovative PPPs, which have less public involvement and more private involvement in this sequence [FHWA website]. However, the categories of PPP toll roads by FHWA is a little complex, and some of the types are not been used in the United States at this time. Basically we can divide all the United States current PPP toll roads into two main categories: privatization of the existing roads, and privatization of new roads.

2.1.1 Development of PPP Toll Roads in the United States

Infrastructure privatization developed much earlier outside the United States, for instance in places like Europe, Latin America, and Asia. According to the World Bank records, in 1997 and 1998, the infrastructure privatization outside of the United States reached a peak of over $110 billion per year [World Bank's Public Private Infrastructures database]. From the last decade of 20th century, the PPP toll roads began developing in the United States. Because of the financial problems of public agencies in transportation facilities, many states enacted legislation allowing PPP highway projects. According to the study of Nossaman in 2006, there are 18 states that have the relevant laws to allow solicited and unsolicited proposals for PPP projects [Nossaman Guthner Knox Elliott LLP, 2006]. Opening in 1995, the SR91 Express Lane project was the first privately funded toll road built in the United States since the 1940s. Until now, approximately $21 billion has been invested in 43 various PPP highway facilities during the last 12 years. Among them, nearly half of the total investments were used on the 18 major highway PPP projects in California, Florida, Texas, and Virginia [Grote, 2006].

In the last two years, there are two multi-billion-dollar PPP toll road projects: Chicago Skyway and Indiana Toll Roads that have become the focus of the PPP field. In 2005, the City of Chicago signed a 99-year concession to lease its 7.8-mile Skyway toll road to the private sector for $1.8 billion. The Chicago Skyway is a landmark in the PPP toll road field, because it is the first long-term leasing toll road in the United States. Subsequently, Indiana leased it's 157-mile Indiana Toll Road for 75 years at $3.8 billion. After those two multi-billion-dollar PPP toll roads, New Jersey and Pennsylvania thereafter began exploring how to get the private sectors involved with their own turnpikes. It is estimated that the potential deal for those two states' turnpikes would cost much more than Indiana Toll Road, between $10 billion and $30 billion [Lettiere et al., 2003]. In addition to the SR91 Express lanes, Chicago Skyway, Indiana Toll Road, there are still some other current PPP toll road projects in the United States, for instance, Virginia Route 895 (Pocahontas Parkway), Dulles Greenway, South Bay Expressway (SR 125), Foley Beach Express, E-470 Toll way [FHWA website]. Based on the study of FHWA in 2006, there are 26 private involvement toll roads, which is 16.6% of all the US toll roads [FHWA website]. The 26 PPP toll roads have a total of 2,207.8 lane miles in all [Perez & Lockwood, 2006].

2.1.2 Toll Rates and Regulation Policies

The purpose of private sectors getting involved into the PPP toll road infrastructure is to make a profit from the toll revenue. Since the private sector is taking over the toll road, they will set the toll rates to charge the road users. The regulation of the private profit and at the protection of public welfare is becoming a challenge to decision-makers.

Currently in the US PPP toll road projects, there are four main regulation methods: (1) concession term duration, (2) private payment, (3) maximum toll rates setting, and (4) maximum toll revenue setting. In practice, it is common to combine several methods together in one specific PPP toll road project to protect the public welfare.

2.1.2.1 Duration of Concession Term

The concession term is the valid lifespan of the PPP projects, and after that duration period, the toll road will be taken over by public. Therefore, the concession term determines how long the toll road will be operated by the private sector. In other words, the concession term determines how long the private sector can get revenue from this toll road. Here are some current US PPP toll road projects' durations. Figure 2.1 summarizes PPP road duration as identified on the websites of each the PPP toll roads.

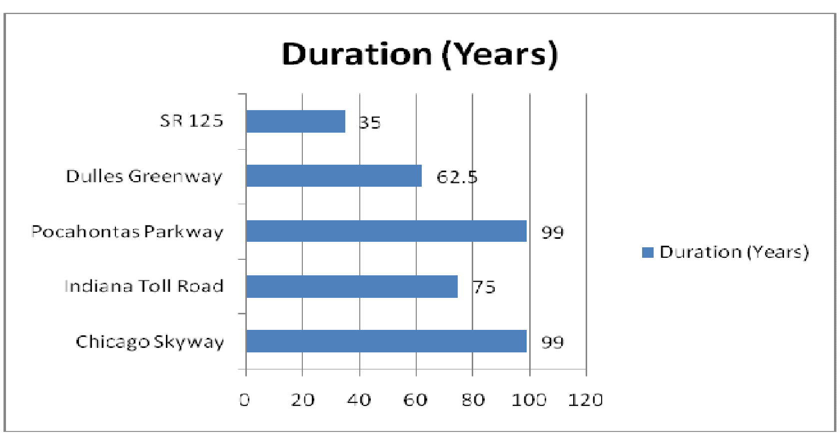


Figure 2.1 PPP Toll Road Durations

In addition to the Foley Beach Express that is a purely private toll road, the longest duration of the current PPP toll road projects is 99 years (Chicago Skyway and Pocahontas Parkway). Even the shortest duration (SR 125) is more than 30 years. There are some debates about the long-term concession. Jose Gomez-Ibanez et al. think excessively long contracts may have uncertainty and unforeseen risk, which will lead to the contract unworkable and need renegotiation [Gómez-Ibáñez et al., 2004]. Phineas Baxandall believes that the massive and unpredictable long-time period will make the government unable to negotiate concessions that “fairly allocate risks, dictates policy, or set a fair price” [Baxandall, 2007].

2.1.2.2 Private Payment

Private payment is the amount of dollars that the private sector will pay for the toll road’s constructions or lease fee to public. For new construction PPP toll road (like Build-Operate-Transfer or Build-Own-Operate), the private sector will pay for the construction costs of the new road. Figure 2.2, identified on the websites of each the PPP toll roads, depicts examples of new construction PPP toll roads’ payments.

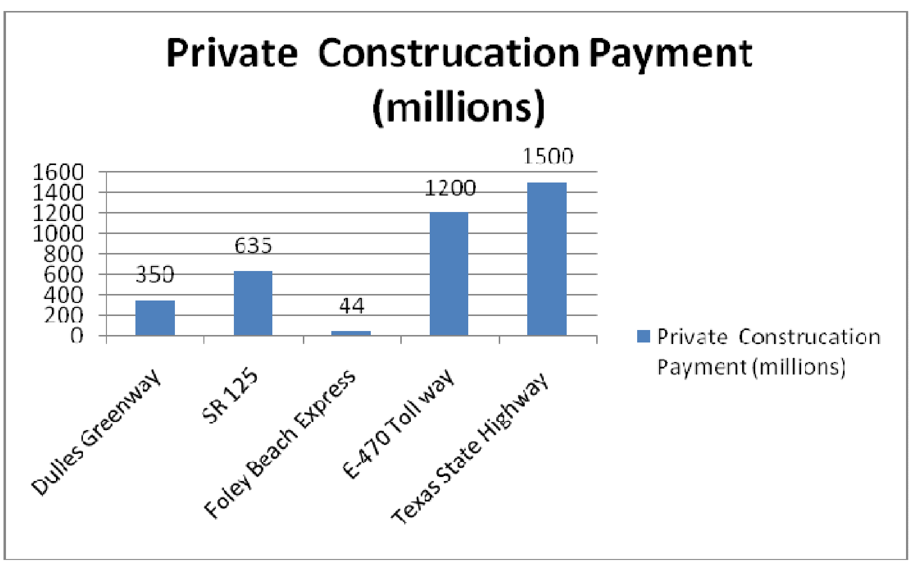


Figure 2.2 PPP Toll Road Construction Payments

The private payment reflects the value of infrastructure in those existing toll roads leasing projects. The amount of the payment depends on the factors of traffic flow projection, leasing duration, and toll rates. Basically, to avoid the underestimate of the value of the leasing transaction, the government will hire lawyers and analysts to conduct asset evaluation and contract enforcement. For instance, the government paid $20 million to Goldman Sachs for financial advice on Indiana Toll Road. Moreover, $9 million was paid for the Chicago Skyway's financial analysis [Schulman & Ridgeway, 2007]. Figure 2.3, identified on the websites of each the PPP toll roads, depicts examples of leasing PPP toll roads' payments.

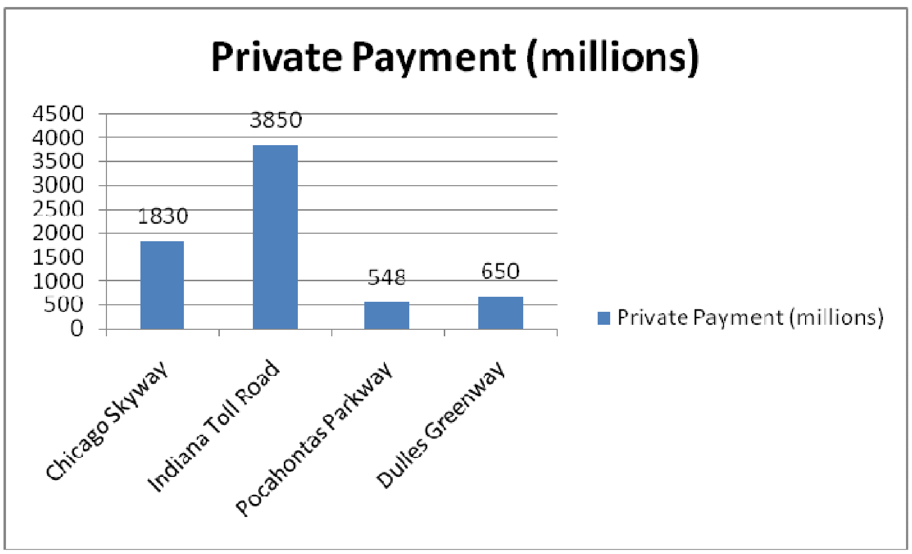


Figure 2.3 PPP Toll Road Leasing Payments

In most of the analysis and evaluation, the revenue generated by the road will be calculated by the formula of road users multiplied by toll rates and adjusted by growth. The state will estimate the traffic flow projection based on the historical performance and traffic studies. Consultants will be hired to calculate the Net Present Value (NPV), which equals to the sum of present value of the annual cash flows, to estimate the asset value and evaluate the leasing bids.

For example, the Indiana Department of Transportation (INDOT), hired the Wilbur Smith Associates to conduct the study of Indiana Toll Road in 2005, which reviewed the trends of traffic and toll revenue of Indiana Toll Road from 1995 to 2005 [Wilbur Smith Associates, 2005 a]. According to that study, we can find that in the fiscal year of 2004-2005, the total number of vehicles in Indiana Toll road 54,683,000 consisting of 44,954,000 passenger cars and 9,728,000 commercial vehicles. From the 1995 to 2005, the average annual percent change of total vehicles is 3.01%. And in the fiscal year of 2004-2005, the total revenue of Indiana Toll Roads is $87,724,000 consisting of $34,443,000 from passenger cars and $53,281,000 from commercial vehicles. From the 1995 to 2005, the average annual percent change of toll revenue is 2.4%. Then the State of Indiana also hired Crowe Chizek and Company LLC to complete a financial analysis of Indiana Toll Road based on the Wilbur Smith Associates' traffic studies. The analysis assumes the operating expense growth at 5.1%, repairs and renovations expense growth at 2.5%, and discount rate at 6%, and calculate the NPV of future cash flows at $1.92 billion [Crowe Chizek and Company LLC, 2006]. The methodology of the toll revenue calculation is to separate the whole 75-year duration into 3 periods with different traffic flow and toll growth rates, and calculate the toll revenue of each period respectively.

Similarly, the Chicago Skyway was also evaluated by the City of Chicago. According to the financial statement for the City of Chicago, which was provided by Deloitte & Touche LLP, the total net deficit of Skyway in 2004, the year before the Skyway was leased out, was $134.5 million, with an increase of $89.5 million compared to 2003. Although the 2004 total vehicles volume was 17.4 million with an average annual percent change of 5.5% from 1995 to 2004 and the 2004 toll revenue was $41.1 million with an average annual percent change of 5.5% from 1995 to 2004 [Deloitte & Touche LLP, 2005]. The financial statement illustrates the Skyway suffered from a deficit when it was operated by a public agency, though the traffic demand continued to increase.

2.1.2.3 Maximum Toll Rates Setting

The maximum toll rate setting method is a method that regulates the private revenue and retains the public welfare by setting a toll rate “ceiling”. According to the agreement, the private operators can charge the road users as much as they wish, so long as the toll rates are lower than the maximum setting. Usually, the concession term is divided into several periods. The maximum toll rates are set differently in each period because of inflation. In practice, the agreement sets a maximum toll rate in a base year, and increases to a specific maximum toll rate every year or every other year in the first 10 years (or maybe a bit longer). After the first 10-year period, the maximum toll rate usually increases annually by the greater of 2% and two different measures of inflation – CPI (Consumer Price Index) or GDP (Gross Domestic Product) per person. For instance, the 99-year Chicago Skyway, the toll rates will increase by $0.5 for 2-axles every 3 years from 2005 to 2017. After 2017, the toll rates will increase annually based on the greater of the CPI, GDP/person, or 2%. Additionally, the maximum toll rates in one specific year are differentiated by the different vehicle types. In practice, the number of axles distinguishes the toll rates of most of the current PPP toll roads in the United States. The more axles the vehicle has, the more tolls they need to pay.

In the Appendix, there are maximum toll rate settings for some current PPP toll road projects in the United States.

2.1.2.4 Maximum Toll Revenue Setting

In addition to the Maximum toll rates setting, there is another regulation method to restrict the private revenue directly – maximum toll revenue setting, which is also called a revenue sharing approach. This method sets the Internal Rate of Return (IRR) as the trigger of revenue sharing. The private sector has to share the toll revenue with the public during the concession term based on the IRR of the PPP project. The higher of the IRR, the more private profit they must share with the public.

In the United States, the Texas State Highway 130 segments 5 & 6 and Virginia Route 895 (Pocahontas Parkway) use this regulation method to restrict the private profit. The revenue sharing provision in the agreement of Texas State Highway 130 divides the project equity return into three bands: 0 ~ 11%, 11% ~ 15%, above 15%. According to the agreement, the Texas Transportation of Department (TxDOT) shares different percentages of private revenue based on different equity returns, from 4.65% up to 50% as shown in Table 2.1 [Saenz, 2006].

Table 2.1 Texas SH 130 Revenue Sharing

Internal Rate of Return (IRR)	Percentage of revenue sharing with TxDOT
0 - 11%	4.65%
11% - 15%	9.30%
ABOVE 15%	50%

Virginia Route 895 (Pocahontas Parkway) is another existing PPP toll road in the United States which uses the method to regulate the private profit. Unlike the Texas State Highway 130, the revenue sharing provision in the 99-year leasing agreement of Pocahontas Parkway allows the private sector to keep all the revenue if the IRR is lower than 6.5%. The IRR in this project is based on the total invested project funds, which is defined as all amounts paid for the acquisition and capital construction and project [Reese, 2006]. Compared to the Texas State Highway 130 project, the IRR of Pocahontas Parkway is calculated on a larger base, instead of just investing equity. This is the reason why the Pocahontas Parkway project sets a narrower IRR band and smaller triggered IRR. Table 2.2 depicts the revenue sharing levels for each IRR band of Pocahontas Parkway [Virginia Department of Transportation & Transurban LLC, 2006].

Table 2.2 Pocahontas Parkway Revenue Sharing

Internal Rate of Return (IRR)	**Percentage of revenue sharing with VDOT**
0 - 6.5%	0
6.5% - 8%	40%
ABOVE 8%	80%

2.1.3 Financial Approaches

The financial approaches indicate how the concessionaires finance PPP toll roads projects. There is always an argument about the higher cost of private investors' capital, because it is believed that the public agencies would get a lower interest loan or debt when raising capital to finance the roads. Dennis Enright believes that there is a full 35% less of the public agencies debts than the private sector can get so that the private sector will pass the additional cost to the public and road users by a 20% to 30% higher toll than the a public ownership toll road [Enright, 2007]. The real-world condition would be much more complicated. However, it is true that public agencies have some advantages in financing road projects by issuing some tax-free bonds or borrowing low interest debts. Some of the existing PPP toll road projects are fully financed by the private assets and loans. For instance, the Chicago Skyway's financial structure was comprised by $882 million private equity that is 48% of the total payment, and $948 million private loans which is 52%, approximately [FHWA website]. The Indiana Toll Road deal cost $3.85 billion. 20% of the total cost was private equity ($770 million), and the other 80%, approximately $3.03 billion, was from private loans [FHWA website]. The Foley Beach Express concessionaire issued $36 million in private bonds to finance this toll road [FHWA website]. Additionally, the Dulles Greenway leasing cost was composed totally of private debt and equity [www.dullesgreenway.com].

However, not all of the PPP toll road projects are financed solely by private equity and loans. The Federal Government and the U.S. Department of Transportation also notice this problem and tried to narrow the financial cost gap between the public and private funding. There are three main measurements to lower the private debt cost and enhance them to get involved in.

i. First, the purpose of theTransportation Infrastructure Finance and Innovation Act (TIFIA) enacted in 1998 was to promote the private sector involvement in road projects by lowering the private sector's cost of capital. The TIFIA provides credit assistances in the forms of secured (direct) loans, loan guarantees, and standby lines of credit to "leverage Federal funds by attracting substantial private and other non-Federal co-investment in critical improvements to the nation's surface transportation system" [TIFIA Website]. Until July 2007, there were more than 13 projects in the United States that were financed with assistance of $3.7 billion TIFIA, which includes the South Bay Expressway ($140 million TIFIA) and Pocahontas Parkway ($150 million TIFIA).

ii. Second, the Department of Transportation is also trying to subsidize the private borrowing cost by offering the private sector tax-exempt bonds for qualifying PPP toll road projects and surface freight transfer projects, besides the TIFIA. Through this private activity bonds, the private developers and operators can receive tax-exempt interest rates for such highway projects. In the United States, there are $15 billion allocated by the Department of Transportation in such tax-exempt bonds for such projects to enhance the private entities' investment in the transportation infrastructure projects.

iii. Finally, the Department of Transportation is also offering the private entities local grants, like right-of-way grants, and compliance with environmental requirement to encourage their involvement. For instance, the entire central Texas Turnpike project receives $511.7 million local grants, of which Texas State Highway 130 is a component.

Above all, we can find that the PPP toll road finance methods are becoming multi-faceted rather than exclusively depending on the private equity and debts. There are various options provided by the federal and states to lower the cost of private financing PPP toll roads. Here is an example of PPP toll road in the United States with multiple financial sources. The South Bay Expressway (SR 125) in California, which was opened in November 2007, was financed by private equity, commercial debts, TIFIA loan, and right-of-way grants as shown in Figure 2.4 [Rawlin, 2005].

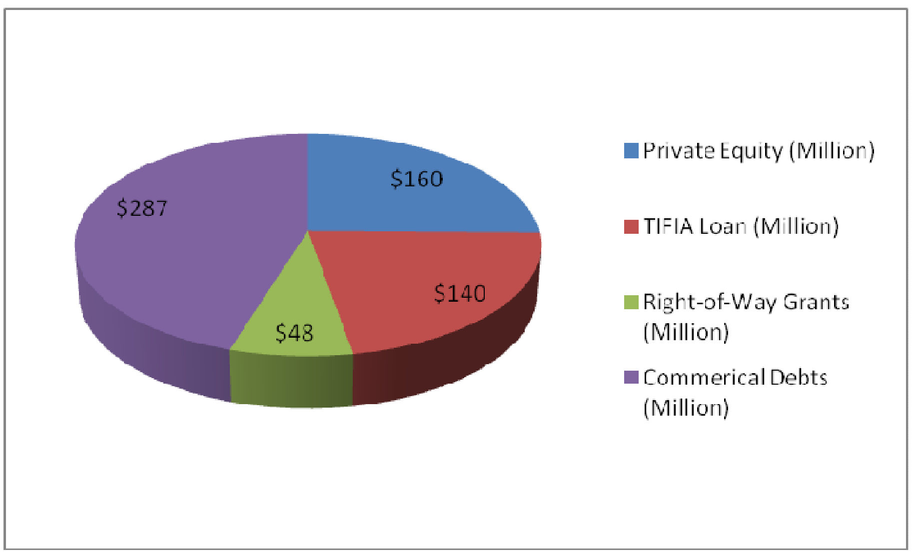


Figure 2.4 South Bay Expressway (SR 125) Finance structure

Another example is the Central Texas Turnpike System, which included SH130, SH45 North, and Loop1. The source of finances for this large Texas highway project was from a variety of sources as shown in Figure 2.5 (TxDOT, 2006).

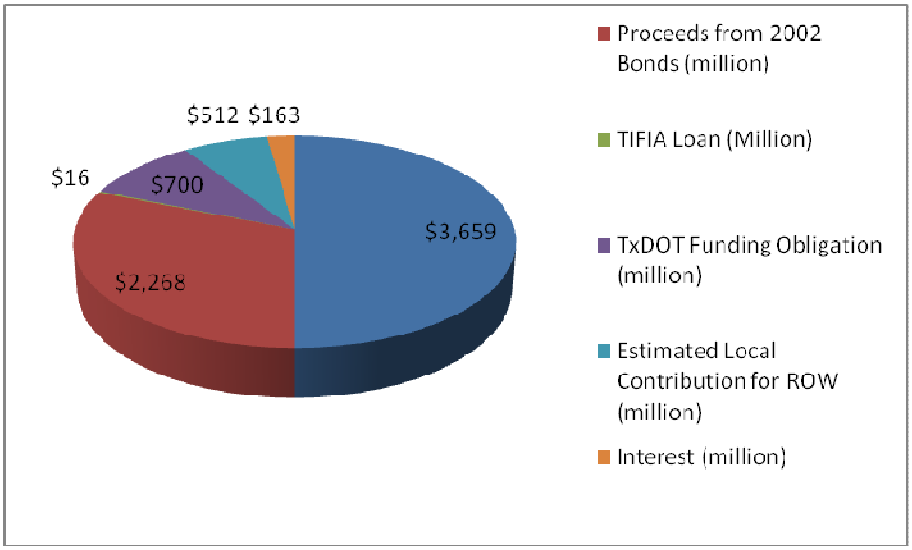


Figure 2.5 Central Texas Turnpike System Finance structure

2.1.4 "Non-compete" clauses and termination provision

Fearing the risk of low traffic demand in toll road, some private sectors try to prohibit the improvement and expansion of the roadways in the area through PPP "non-compete" clause in contract or agreements. There is always a hot debate about the non-complete clause.

The SR91 Express Lanes project, the first PPP toll road in the United States, was bought back by Orange County Transportation Authority (OCTA) from the California Private Transportation Company (CPTC), the former private operator of SR91 Express Lanes, with $207.5 million in early 2003 [Poole, 1999]. One of the reasons that the public suspended the 35-year leasing agreement and bought it back from the private operator was because of the "non-compete" clause in the leasing agreement signed in 1995, which prevented public transportation agencies from increasing highway capacity on other roads within one and one-half-miles of SR91. The increase in traffic demand in this area resulted in traffic congestion since the roadway capacity could not be expanded.

In addition to the SR91 Express Lanes, the E-470 Tollway, Virginia Route 895 (Pocahontas Parkway), and Indiana Toll Road projects are also facing such a non-compete clause in their concession. According to the agreement of E-470, the public would lower the speed limit from 55 mph to 45 mph and install traffic signals on the road nearby to discourage the potential E-470 road users from choosing alternative routes [Rocky Mountain News, 2005]. The Indiana Toll Road project has a similar though less extensive “non-compete” clause. The concession requires that the state compensate the private sector if the public construction reduces the toll revenue of Indiana Toll Road. In that case, the public has some additional costs if they decide to construct a transportation facility [Tollroadsnews, 2006 a]. The Virginia Department of Transportation (VDOT) has to compensate the transurban company, the private operator of Pocahontas Parkway, for the loss of revenue if there is any new highway crossing over the James River within 3 miles of the centerline of the Parkway Bridge. But in the leasing agreement of Pocahontas Parkway, there is also a related provision to assure the level of service. If the private operator cannot enhance capacity to address the congestion problem within a specific time period, if any, then the “non-compete” clause in the leasing agreements become invalid [Tollroadsnews, 2006 b].

The “non-compete” clauses that are used in the real-world PPP toll road projects can be divided into three categories. The first type is a no new constructions clause. According to this clause, within a certain area, the public sector cannot build any new highway project or any upgrade of existing public road capacity. SR91 is in this category. The second type is a compensation cost for a new project. This clause allows new highway construction projects or existing highway capacity expansion project. However, the public will suffer additional costs by paying the compensation of the loss to the private sector if they have any new project. The examples are Indiana Toll Road and Pocahontas Parkway. Other than these two, the VDOT are considering the non-compete clause in some new PPP toll road. The Route 460 may have this type of non-compete clause, which requires the VDOT to pay the compensation to the private agency if there are any new lanes added to the Route 460. The last type of non-compete clause is to lower the posting speed of the public roads parallel to the PPP toll road or within certain area. The E-470 Tollway agreement has such a “non-compete” clause.

Some PPP toll road agreements also have the termination provision in case there is any unforeseen unworkable condition in the uncertainty of long-term concession duration. The termination provision gives the parties of PPP toll road projects to terminate the contract with a cost after negotiation. For example, according to the leasing agreement of Pocahontas Parkway, the VDOT has the right to terminate the leasing agreement at any time for convenience after 40 years, at a cost [Saenz, 2006]. The 40-year time limit was set because it is estimated that the private operator can pay off all liabilities in that time. The cost of termination should be an amount that at least is sufficient to pay the outstanding debt on the Project plus an agreed minimum equity return to the private operator [Kulper, 2006]. With this provision, the public have the choice to terminate the 99-year lease earlier for the Commonwealth's best interests, if necessary. Actually, it is a provision that would protect the public welfare in the project.

2.1.5 Current Toll Rates of Some Toll Roads in the US

In this section, we will get a general idea of the current toll rates of some existing toll roads in the United States by reviewing them respectively. Appendix B shows the toll rates of most of the current PPP toll roads in the US.

2.2. Practical Level Discussion

For a long time, the core debate about the PPP toll road projects is whether the public receives the full value of the assets in road transactions, and how much profit the private sector gains in the projects. The purpose of the private companies getting involved in the transportation investment is to make some profit. Nevertheless how is the public sector going to get a fair price for a PPP toll road? In addition, how does the public sector regulate the private revenue from the PPP toll road project to retain the public welfare are always concerned? In practice, the government will hire a transportation consulting company to do the traffic survey and projection study, and also hire a third-party financial agency to evaluate the private biddings after issuing the request for proposals.

Consider the Indiana Toll Road as an example. The Wilbur Smith Associates prepared a rate review and revenue study for Indiana Toll Road in August 2005, and a fiscal report for Indiana Toll Road in December 2005, to the State of Indiana and Indiana Department of Transportation. The trend of historical toll rates is reviewed, and the future toll schedule was proposed in that study [Wilbur Smith Associates, 2005 b]. They also reviewed the historical revenue of Indiana Toll Road, and estimated the future revenue based on the traffic survey and proposed toll rates. The Crowe Chizek and Company LLC was hired by the State of Indiana to do the financial evaluation to estimate the total value of the assets of Indiana Toll Road based on the results of review and traffic projection from Wilbur Smith Associates. The government negotiates the private payment according to the financial evaluation and sets the maximum toll rates to regulate the private revenue. However, we noticed that even in the base year, the maximum toll rates set in the leasing agreement of Indiana Toll Road was a bit higher than the scheduled toll rates proposed by the Wilbur Smith Associates' study. The increase of the maximum toll rate is higher than the proposed.

As mentioned in last section, the financial evaluation for Indiana Toll Road resulted in the total NPV for Indiana Toll Road in 75-year duration as $1.92 billion. Compared to the private payment $3.85 billion, the Indiana Toll Road seems to be a pretty good investment for the public. In fact, some people have other opinions. Dennis J. Enright evaluated the Indiana Toll Roads revenue conditions in his research report. Based on the historical trend of traffic growth, he divided the annual traffic growth into four categories: no growth, historical growth (1.5%), moderate growth (1%), aggressive growth (3%), and estimated the total toll revenue based on the five annual toll rates increase (2%, 3% CPI, 4% GDP, 5.5% GDP, and 7% GDP). The result shows that the minimum toll revenue in the 75-year period is $2.1 billion, and maximum revenue is $60.5 billion. The private sector can roughly get the $3.85 billion back even in the condition of 1.5% annual traffic growth and 2% annual toll rates increase, which means the private sector can make additional profits as long as either traffic growth or toll rate increase exceeds this level [Enright, 2006]. Professor Roger Skurski at the University of Notre Dame also believes that the toll road values should be increased to $11.38 billion based on reasonable and economically assumptions on tolls, traffic and discounting [Skurski, 2006].

In fact, the Macquarie company, the private operator of Indiana Toll Road, presented to those investors “anticipated 15 year payback period to equity”, and estimated the investment IRR between 12.5% and 13.5% [Macquarie Investment Group, 2006]. There is a similar situation for the Chicago Skyway project. One of the private investors for the Skyway project, Cintra, also revealed that the expected investment return on the equity was 12.5% [Enright, 2007]. Therefore, here we suggest that the Indiana Toll Road and the Skyway should have a revenue sharing provision in the agreement, along with the maximum toll rate setting regulation policy. In that case, the public will receive some additional payment if the private sectors make much more profit by charging the road users.

Another argument is about the efficiency gain in the PPP toll roads. At first, people think the private sector efficiency advantages, if any, will be offset by the higher debt costs of the private sector. But as the introduction of TIFIA and other measures to lower the borrowing cost of PPP projects, it is believed that the private sector can get a higher efficiency gain in the road projects than public agencies. However, some researchers do not agree to that point. We will discuss this problem in next section.

2.3. Theoretical Research Level Review

After reviewing the current PPP toll road projects in the United States, we know the situation and development of PPP toll road projects in practice. Now we turn to the theoretical research part and see the PPP toll roads from the view of academics.

The academic studies and research about PPP toll roads can be separated into three topics: private revenue and public welfare, risk allocation study, and innovative PPP types.

2.3.1 Private Revenue and Public Welfare

The argument about the private revenue and public welfare is always a focus of discussion in the theoretical research about PPP toll roads. Will the privatization really increase the efficiencies of the toll roads? How to identify the winners and losers of those PPP toll roads projects? How to regulate the private sector to retain more welfare? How to estimate the toll revenue quantitatively? The questions have been studied with attempts to solve them. Some researchers think about the efficiency argument and try to identify the winners and losers of those PPP toll road projects qualitatively. Other studies try to make some assumptions and build mathematical models to identify winners and losers, or test different regulation policies by estimating the toll revenue and social welfare quantitatively.

2.3.2 Qualitative Study

One of the main reasons for the introduction of the PPP model is that there is a general idea that the private sector can get a higher efficiency in projects than public agencies. But Gomez-Ibanez et al. raise an argument about this in their study about the feasibility of road and solid waste privatization in the United States, from the view of the public [Gomez-Ibanez et al., 1991]. The study points out that the private operators can only achieve low cost and high-efficiency in labor-intensive services, but not in capital-intensive services. It is easier for private agencies to get high productivity, lower wage rates, and more donations of right-of-way than public agencies. They think the largest efficiency gains in the PPP toll road projects are in the construction process, not in facility operation. Currently in the United States, most road construction projects are contracted to private firms.

Gomez-Ibanez et al. analyzed the relationship of public and private in PPP toll projects [Gomez-Ibanez et al., 1991]. The private operators may suffer higher interest debt than public projects, and are more likely to set the toll rates higher than marginal costs and pursue a monopoly state. So the public agencies have to regulate the toll rates of the private sector to protect the road users, while the regulation may cause the inefficiency of the facility. Klen and fielding suggested that state governments do not place unreasonable provisions in the agreement to avoid scaring the private sector away from the projects. They also indicated that the modern private toll road projects should all get the local and environmental clearance before getting the project under way. These were discussed in their study that compared the five modern private toll road projects (The Dulles extension project in Virginia, SR91, Rt. 57 extension, SR 125, AND Mid-state road project in California) and the private toll road projects of the 19th Century, particularly those private turnpike companies of the northeastern states prior to 1845 [Klen & Fielding, 1992].

As mentioned before, the identification of the winners and losers of PPP toll road projects is always contestable. Gomez-Ibanez et al. also discussed the winners and losers of PPP projects in general. They concluded that the most likely losers in the privatization of toll road are labor and landowners, because of the lower labor wage and greater success of private sectors in persuading the donation of lands than public agencies. The most likely winners are public governments and local taxpayers because they can gain part of the efficiency and low cost of private construction. The private sectors may become winners if they can retain some gains from the efficiency and low cost of private construction, rather than passing them to the road users in the form of low toll rates and better services under the competition or regulation. The road users are in a similar situation with private sectors. About this winners and losers discussion, John H. Foote raised his opinion about this problem based on a specify project – Chicago Skyway [Foote, 2006]. He agreed that the taxpayers, city council, and the private sector are winners, while adding that the region be one loser in the Chicago Skyway project. The road users are hard to define, because they will benefit from the better service but suffer higher toll rates.

2.3.3 Mathematical Models

Following some general qualitative winners and losers' discussion, it is common to see quantitative analysis. Many researchers use different mathematical models and simulations to estimate the private profit and public welfare. In that case, they can identify the winners and losers of the PPP toll road projects quantitatively, and test different regulation policies' effect numerically. Based on the complexity of those models, we divide them into four categories here, and review them respectively.

2.3.3.1 One Single Toll Road Models

Wright and Coloma as well as De Rus and Romero studied the PPP toll road based on a theoretical environment of just one toll road. Both of these studies built a single toll road model to discuss quantitatively in what situation the private sector can make profit from a PPP toll road project [Wright & Coloma, 1997; De Rus & Romero, 2004].

Wright and Coloma conducted their study based on two simple options: building a new highway or upgrading an existing one, and assumed the private get the breakeven toll rates under different real interest rates, operation years, and traffic demand levels for both of the two projects through simulation. The paper showed simulation results in the case of no long-term loans, the private sector can neither finance the construction of the new highway nor upgrade the capacity of the existing highway when the real interest rate is between 12% to 18% or more. Based on their model and simulation, they concluded that the private sector could only get profit in two situations: First, congestion reliever in metropolitan roads, where users will accept high toll rates. Second, upgrades of interurban highways with high traffic potential, low construction costs, or both.

De Rus and Romero discussed the possibility of getting both the involvement of the private sector and the optimal pricing of the toll road, simultaneously. In this model, they define the total social cost consisting of producer costs (which have components of constructing, maintaining and operating costs) and user costs (which have components of vehicle expense and time). Based on this definition, the authors introduced the function of the total social costs. Moreover, the authors used the inverse demand function to present the users' willingness to choose the toll road, which is related to the travel cost and toll, and hence to calculate the toll revenue of the road. With revenue and cost function, it can maximize the social surplus, and get the optimal pricing function, consisting of maintenance and operation cost caused by vehicle damages and delay cost imposed by other road users. From the model, they determined that the revenue is able to cover the maintenance and operation cost, but may not cover the investment cost. Furthermore, the authors also studied the issue of concession term period. By forming a bidding toll function with concession period expected demand, and cost, the authors discussed the concession period under constant demand and variable demand situations. At the end of the paper, they concluded that the variable term concessions could help in the introduction of optimal road pricing in practice, since it is very difficult to apply optimal pricing in the real-world. The road users are assumed to be homogeneous road users in this model.

Wang and Verhoef built a little more complex single toll road model, in which the private highway operator will compete with the private transit operator [Wang & Verhoef, 2004]. They assumed a condition that the private highway operator, private transit operator, who use the same highway for their service, and a railway line which is parallel to the highway. For demand equilibrium, the authors used the density function of the distribution of value of times across the user population to get the market shares of each of the three modes. As to the market equilibrium, the authors used game theory and analyzed the result under 6 scenarios: without transit service, Game A-highway operator as the leader and decide the toll first, Game B-transit operator as the leader and decide the fare and frequencies first, Game C-Nash game which means both of the operators make their decision simultaneously, Game D-service frequency is fixed while fare and tolls are flexible, and monopoly case which means only one service provider the highway and transit. The result showed that in the scenario of transit operator as the leader, the quality of transit service will be best in contrast to the Nash game scenario lead to the worst, although the transit operator can only get a breakeven profit in the Game B scenario. The total profit will be the highest in the monopoly scenario. They concluded that the transit operator prefers to follow the highway operator to decide their fare and service frequency, while the highway operator is in the reverse position.

The model developed in the study above considers the competition of private operator with the transit mode and parallel railway line, which has not been mentioned in other journal papers (Innovation). Moreover the study considered the heterogeneity of different travelers. The study used game theory to develop several scenarios, including Nash and Stackelberg (leader-follower) games, which are also been used in the study by De Palma and Lindsey to represent different scenarios of mix ownership situations of two parallel routes [De Palma & Lindsey, 1998]. Nevertheless, Wang's model was built on a simple road environment, without even one parallel competing road. In addition, we have to point out that the model used in the paper assumes the travel time is constant without considering the effect of congestion, and uses a simple linear access-pricing scheme and fix fee for each trip, which are not practical in the real world.

2.3.3.2 Two Parallel Routes in One OD Pair

The mathematical models built based on two parallel routes in one origin-destination (OD) pair are very common. In a two parallel route model, the researchers can test and simulate different scenarios of ownership, competition, and regulation methods. Many studies and researchers build this type of model, with different assumptions, to investigate the private profit and social welfare quantitatively.

De Palma and Lindsey built a model based on two parallel routes with different capacity and free-flow travel time in one OD pair. The study contained seven scenarios for the parallel routes: two benchmarks (two free access routes, two public roads with queue-eliminating pricing), tolling of one route (private route parallel to free access route, public route parallel to free access route), tolling of both routes (private duopoly, Nash equilibrium – public route parallel to private route, Stackelberg – mixed duopoly with leadership on the public route) [De Palma & Lindsey, 1998]. Comparing this to the previous studies, the innovation of this paper is that the model integrates the queue-eliminating tolls and initial tolls system instead of flat tolls. Additionally, it demonstrated that both the private and public toll roads have higher efficiency gains when the flat tolling method is replaced. The numerical comparison of the model showed that the Nash equilibrium scenario and Stackelberg would get the most social surplus, comparing to other scenarios. Based on this model result, the private duopoly ownership regime will lead to the highest efficiency gains if neither route has a dominant fraction of total capacity, while the mixed duopoly ownership regime (public-private) has a lower efficiency gain than the private competition scenario. If the two routes have almost equal capacities, a private route parallel to a free access route will yield the most efficiency. As before, this study does not consider the heterogeneity of different road users.

Tsai and Chu developed a model for Build-Operate-Transfer (BOT) toll road of five different cases representing five different constraints or regulation policies, respectively [Tsai & Chu, 2003]. The five scenarios are no BOT with maximum social welfare scenario; no BOT with maximum social welfare scenario while the finance breakeven of second road, BOT scenario without regulation, BOT scenario with a minimum flow constraint, and BOT scenario with a maximum travel time. They compared the results of different cases with similar parameters values to get the influence of different regulation methods or constraints. Additionally, they changed the values of parameters, compared the results with former one's calculated from unchanged parameters, and found out the influence of the technology of the building procedure and the influence of stricter regulation policy of the same regulation method. The authors concluded that the regulation has less power under the condition of low elastic demand, and the high private efficiency will lead to more welfare gain even with regulation, than the scenario without BOT project. They discussed the problem of identifying efficiency gain quantitatively in the BOT toll road projects. Similarly, this model does not integrate road users' heterogeneity.

Gronau built a model based on the assumption that the two perfectly substitutable roads scenario-one toll road and one free road, which can be counted as one scenario of the study of De Palma and Lindsey [Gronau, 1997]. In this model, the cost of travel, including the vehicle operating cost and value of travel time, is the criterion of the road users' route choices. The study assumed that the road users are homogeneous to ignore their demographical differences. The result of comparison of the welfare-maximizing toll and profit-maximizing toll showed that the profit-maximizing toll is higher than the optimal toll. In addition, they found the smaller the elasticity of travel demand, the more congested the free alternative road. This study is more like the "private route parallel to free access route" scenario discussion of the De Palma and Lindsey study, but it considered this situation under the varied road capacity.

Viton discussed the feasibility of making a profit using the private toll road [Viton, 1995]. He made a base assumption that building a private toll road competes with an existing public free road alongside, and used a discrete choice model to simulate the road users' route choice to get the function calculating the number of road users using this toll road. He then converted the different types of vehicles into an equivalent number of passenger cars to describe the congestion impacts, and calculated travel time and toll revenue. After building the model, he used some common empirical numerical input to implement the model and calculate the profit of the road. By different input data sources to the model that are from the United States experience in the early 1990s, the simulation results are used to compare two different conditions: intercity road scenario and urban highway scenario. The simulation result indicates that the private sector can guarantee profit especially in the urban scenario, and the profit remains possible even under some reasonable regulation in this scenario. While, the profitability are more likely to fail when the distance is long and traffic is light.

However the paper does not consider the welfare impacts after the private toll road participation. Viton also raised a question about the public road finance system: the tax-payer would not be willing to pay for the taxes which are used for public highway facilities finance since the public road are just supplemental to the private one, and they think they will not use the public highways. This study researched the influence of different road types for private toll road project, which is unique comparing with other journal papers. This model also considered the maintenance cost of the private road and varied road capacity condition, but ignored the road users' heterogeneity.

2.3.3.3 Two-dimension Models in General Road Network

Apparently, two parallel routes in one OD pair is a simple basic assumption for the models we discussed above. However, in practice, it is difficult to analyze a specific road without the influence of other highways nearby. We need to analyze the condition of a specific toll road based on a general road network in the real world. So, some researchers try to build two-dimension (toll-capacity) models in general road networks.

Yang and Meng built a basic bi-level framework with the upper-level program to maximize the private profit and the lower-level program to determine the network (BOT links and free links) flow equilibrium, under a BOT toll road project in a general equilibrium networks with numerous of nodes and links, rather than one single OD pair [Yang & Meng, 2000]. Furthermore, the study developed different objective functions of the models under four different constraints or regulation policies: monopoly scenario, competition scenario, the first-best social optimum, and the second-best social optimum. They then used a numerical example (a case study of an inter-city expressway in the Pearl River Delta Region of South China) to estimate the parameters and get the numerical results to investigate the project profitability and social welfare gain of a new toll road in a toll-capacity dimensional space, under different regulation policies described before. The model was developed to help the private sector to identify their profit in a BOT project, and assist the public sector to know the welfare gain from the project.

The advantage of this model is a two-dimensional capacity-toll space to consider private profit feasibility and welfare in a general road network, instead of simple parallel routes in one OD pair, although, they still ignore the effect of different Value of Time (VOT) to the simulation results.

Based on the work by Yang and Meng, Chen et al. developed a simulation-optimization framework to evaluate the feasibility of the private sector achieving the desire profit in a BOT Project [Chen et al., 2001]. They first used a bi-level formulation with the upper-level program to maximize the private profit and the lower-level program to determine the network (BOT links and free links) flow equilibrium, which was built by Yang and Meng (2000). They then introduced a probability density function of the private financial profit to assess the risk of the project by calculating the probability of achieving the desired profit. Implementing this method into a case study of an inter-city expressway in the Pearl River Delta Region of South China, they calculated the optimal toll and optimal capacity for this project and concluded that the capacity has a greater impact than toll to the financial feasibility. They also pointed out that the simple construction and operation cost function they used in this study needs to be improved in the future. Moreover, the study just focused on the private financial feasibility, rather than considering the gain or loss of the public welfare and those road users.

Since the two-dimensional capacity-toll framework developed by Yang and Meng assumes the homogeneity of road users, Yang and Huang considered heterogeneous users factors based on this two-dimensional capacity-toll model. In this study, they categorized the road users into different groups by their different Value of Time (VOT), and used the two-dimensional capacity-toll model to estimate the private profit and social welfare of a specific BOT toll road project in the general road network. They used a discrete multi-class approach to divide the whole population of potential road users into several groups and each one can be assumed to have an average VOT belonging to some interval, and can be characterized by class-specify demand function. The road users make the route choice decision based on the minimum travel time and cost when facing the general network. Since the flow on the link will affect the travel time of the route, the travel time will affect the road users' route choice, inversely. Therefore, the iterations would end until the multi-class network equilibrium is achieved. The study uses the case of an inter-city expressway in the Pearl River Delta Region of South China as a numerical simulation, and compares the numerical results of the model with heterogeneous users with different VOT categories and homogeneous users with one single VOT. The comparison shows that the homogeneous users model may result in an overestimation at a lower toll) of the traffic flow and private profit, or underestimated at a higher toll, and may also lead to an over-investment on a BOT toll road. This study just considered the situation of a single private operator without competitive private sectors.

Based on the assumptions of homogeneous of degree zero link travel time function and constant return to scale in road construction, Xiao et al. (2006) studied the toll and capacity competition among private roads with parallel roads in a general network, under Nash equilibrium and social optimum scenario respectively. Through comparison of the efficiency of the above two scenario, the authors established the upper bound on the inefficiency of a toll road oligopoly, and found that the inefficiency bound declines with an increase in the number of roads. When the market becomes duopoly status, the inefficiency bound will have a sharp decrease. The authors concluded that the private firms would try to keep their road in a level of volume- capacity ratio to make more profit in the competition condition, which means the competition does not necessarily reduce the road congestion. Also, they found if the market changes from oligopoly to perfect competition, the tolls and capacities of roads will change from the ones under Nash equilibrium to under social optimal scenario. This study's conclusions are obtained based on the assumption that the profit is determined by the capacity and toll simultaneously. In other words, neither of the two factors can affect the profit solely, which is unrealistic in the real world.

2.3.3.4 Three-dimensional Model in General Road Network

Lei Zhang added the time dimension based on the previous two-dimension mathematical models in general road network. In this new model, the private sector can invest in the new freeway during the life span of the project [Zhang, 2008]. He assumed that the revenue would be used to expand the capacity of links with highest benefit cost ratios unless all remaining links have a benefit cost ratio less than 1 or the revenues are used up. He validated the model with the Minnesota Twin Cities' data. From the simulation results in Twin Cities of this model, based on the competition of the public routes in the road network, the private would get 18.2% annual investment return even without any regulation policies, and only 16.4% welfare gain will be distributed to the road users.

There are two limitations for this three-dimensional model in a general road network. First, it assumes a uniform annual traffic growth. Second, it assumes the homogeneous travelers' VOT, which may result in traffic flow and private profit overestimation at lower toll, or underestimation at higher toll, and may lead to over-investment on a BOT toll road, according to the previous study of Yang and Huang.

2.3.4 Study about Risk Allocation

Risk allocation of PPP toll road projects is another contestable topic of academic study focused. Study for Risk allocation in PPP toll road is to identify the potential risk in the different phases of the projects and try to mitigate the risks. On the FHWA website, a table presented most of the risks in the PPP toll road projects [FHWA website].

Pointing out that the different objectives of both parties of the Public-Private Partnership toll road projects concession, Lockwood et al. concluded that whether a PPP toll road project is successful depends on whether both of the two sectors can achieve their objectives [Lockwood et al., 2000]. This paper identified the four main risks of PPP toll road projects: Development risk, Construction (completion) risk, Operating risk, Economic and political risks. Reviewing some current global practices of PPP toll road projects, the study suggested some approaches to reduce the project risk, like cost-sharing, careful risk mitigation, efficient risk allocation, and commercialization.

Abdul-Malak et al. categorized the possible risk among participants based on the different phases of a BOT transportation projects [Abdul-Malak et al., 2001]. According to their study, there are five categories: pre-contractual risk, political risk, construction and completion risk, operating and commercial risk, payment and financial risk. They analyzed them respectively and raised the alleviation methods for each risk in different phases to mitigate and reduce them. However, this study is more concerned about the risk of the private profit feasibility, rather than the public welfare.

Cesar Queiroz first reviewed the reasons that discourage the private agencies from getting involved in the road financing, which include low traffic volumes, lack of appropriate legal framework, uncertainty of economic and political, and consequent high perception of risks [Queiroz, 2007], therefore, the purpose is to discuss the partial risk guarantee to encourage the private sector to get involved in the road finance. In his study, he suggests a standard process (a 10-step process) to choose and launch appropriate PPP projects, and mentions the application of the World Bank Toolkit. Additionally, he also suggested that there should be some government finance support for the private sector to ensure “the mobilization of large amounts of private capital.” In other word, encourage the private firms to get involved in the toll road projects by sharing the risk. There are five support mechanisms mentioned in his study: equity guarantees, debt guarantees, shadow toll, availability fee, minimum traffic or revenue guarantees.

Ahemd M. Abdel Aziz reviewed the usage-based payment structure, mechanism, objectives, and risk allocation in his paper [Abdel Aziz, 2007]. Then he compared different payment mechanism structures based on several current Public-Private Partnership (PPP) projects in British Columbia in Canada. Through the comparison and analysis, he recommended the service availability payments and management-related payments as the payment mechanism, and the usage payment as a “bonus” incentive payment to the private sector. However, the aim of his study was to reduce the risk of the private constructor, so it does not mention the risk allocation from the perspective of public sector.

2.3.5 Innovative PPP System

Robuste et al. introduced a new approach to set the toll rates. Instead of a strictly financial mechanism, the toll rate is a variable fare determined by different performances, such as timesavings, increment of safety, increment of regularity of travel time, usage, V/C ratio, of the toll road and alternative roads [Robuste et al., 2003]. In that case the operators can be motivated to operate the road efficiently. This study is an innovative type of shadow toll road. It looks like the rudiment of the Concurrent Real and Shadow Tolling (CRAST) model.

Patrick DeCorla-Souza introduced a new PPP Model --- the Concurrent Real and Shadow Tolling (CRAST) model to finance and operate a transportation system of toll road and Bus Rapid Transit (BRT) in major metropolitan areas [DeCorla-Souza, 2005]. Under the new PPP system, the private sector can set the real toll rates to manage the traffic demand, while they cannot get any of the toll revenue. The government will get the revenue and compensate the private sector by a flat shadow toll paid by for each vehicle served at free-flow speeds during rush hours when tolling is in effect. In that case, the new BRT service and facility can be self-financed by the toll revenue.

Based on the CRAST model Patrick DeCorla-Souza introduced in 2005, he also introduced a new financing model in order to make the existing highway system more efficiently and maximize the social benefit [DeCorla-Souza, 2006]. The new Operate-Design-Build-Operate (ODBO) model has two phases in general. In the first phase, the government will introduce the toll into the existing congestion facilities during rush hour to improve the congestion condition. The private sector will be encouraged to get involved in roadway operation, management, maintenance and tolling under a short-term contract. The CRAST model will be used here. In the Phase 2, based on toll and traffic condition in phase 1, the public can prioritize the roadways' capacity expansion. The private agencies would be encouraged to finance, design, build, operate and collect the tolls of the new facility. The model can reduce the risk about the uncertainty of the toll traffic and revenue forecast since the contract of Phase 2 is based on the condition of phase 1. The paper also summarizes a 6-step process for how to integrate the PPP into the new model. It simulates the model applied in the Washington DC metropolitan area, while the analysis result shows that the toll revenue can guarantee the self-finance of the highway project.

Mayer discussed and reviewed several regulation approaches, which are used to retain the revenues for the public sector, of the PPP toll road projects [Mayer, 2007]. These approaches included refinancing provisions, toll rate limits, rebalancing provisions, dynamic concession terms, IRR-based or gross revenue-based revenue sharing. She recommends the revenue sharing approach because it is more flexible in the process of regulation, makes the public more of a participant in the project and shares upside gains. At the end of the paper, she further reviews some existing PPP projects using the revenue sharing approaches, such as the Texas State Highway 130 Segments 5&6, Pocahontas Parkway (VA, US), West-Link Toll Bridge (Dublin Area, Republic of Ireland).

2.4 Theoretical Level Discussions

Mathematical models are used to identify the public welfare and private profit numerically by calculating the social surplus and profit feasibility. The models are different from each other in many aspects, such as the travelers' homogeneity or heterogeneity of demographical features, regulation scenarios, and so on, but the route choice function of all models pretty much depend on the factors of travel cost, and travel time which can also be valued by the cost. The travel time and the traffic flow on a specific route interlock and have influence on each other. The traffic flow on the link will affect the travel time of the route, and the travel time will change the road users' route choice, inversely.

The main differences of those models are mainly in the following aspects:

The difference in the numbers of the roads in model

In some studies, the researchers build their models just including one toll road. They focus on one single toll road, and study its capacity upgrade, profit feasibility, and optimal pricing without considering the influence of the alternative routes nearby. Apparently, it is a very simple assumption for the situation in the real world. To consider the competition of the alternative routes nearby the PPP toll road, some people try to develop their model with two parallel routes in one OD pair. With different competition situations, ownership scenarios, and regulation policies, they can get the different simulation results in different scenarios and compare them. To make the model more realistic, some people develop their models in a road network background, which is more complex than the one OD pair scenario. Furthermore, to predict and estimate the PPP toll road performance and revenue in a specific time, some researchers add the time-dimension into the road network models.

The road users' homogeneity or heterogeneity of demographical features

To simplify the model, some studies assume that the road users are homogeneous. Nevertheless, obviously, in the real world, the road users have different demographical features, which lead to their different Value of Time (VOT). Apparently, some researchers have also noticed this issue, so they have attempted to integrate the heterogeneous traveler's VOT into their models. Based on the study of Yang and Huang, the homogeneous users' assumption may lead to the overestimation of the traffic flow and private profit at lower toll, or underestimation of them at higher toll.

Intercity highway Vs. Urban highway

There are some models that take into account the influence of different facility types of the toll roads. Generally, the urban highway road users are more acceptable to high tolls, the private operators are more likely to make a profit for urban highway projects, even under some reasonable regulation. However, profit from an intercity highway is less feasible, especially during long distance, light traffic, or high construction cost.

Different competition situations

In different models, the researchers developed different competition and ownership situations: one road tolling with free access, mix-ownership, private monopoly, private oligopoly, or the competition of private road operator with other transportation modes.

Maintenance and operation cost function

In the models, not all of them consider the expenditure of road maintenance and operation cost when calculating the private profit. The formula of maintenance and operation cost developed by Viton (1995) is widely used in the research.

A general review chart for the models that are discussed above is show in appendix C. The study of risk allocation in PPP toll road projects try to categorizes the risk of the project based on the different phases of project. Then they suggest the mitigation methods to address them politically or economically. Moreover, they try to introduce some new payment structures to mitigate the project's risk. However, most of the research studies about PPP toll road projects' risks are focused on how to reduce the risk of the private sector in order to encourage them to invest in the PPP toll road projects, but they fail to consider the risk allocation problem from the perspective of public.

Based on the existing PPP system, payment structure, and regulation methods, people are trying to improve them and introduce some innovative systems. The CRAST system is an innovative shadow toll road system, which tries to motivate the private operators to keep the PPP toll road free flowing. However, the studies do not discuss whether the free-flowing condition is really the most efficient status for operation.

3. Gap between the Practical Needs and Research Results

Now that we have reviewed the practical part and academic part in the PPP toll road field, we can find there are many debates about the results and methods of evaluation for specify practical projects. On the other hand, many of the theoretical research studies have been completed, and provided some qualitative conclusions or quantitative tools. Apparently, there are some gaps between the research results and the practical needs which hinder the practical application of the theoretical study and model tools.

Simple assumptions of those models

Absolutely, no model is a perfect match for the real-world situation. The theoretical models always have some assumptions to simplify the complex real condition. For instance, some models assume that travelers have homogeneous demographical features, like VOT. Some people build models with a simple linear access-pricing scheme that results in fixed cost for each trip without considering the congestion effects. Some people estimate the private profit feasibility without private loans, which is very rarely in practical projects.

Flat toll system

In the real world, some PPP toll roads, such as the SR 91 Express Lanes, are not using flat toll rates. While, in the theoretical studies, few of them discuss the situation of time-varied toll rates or congestion tolls, and integrate the time-varied toll rates into their quantitative model.

Uncertainty of models

Those mathematical models with only one single road or two parallel routes are apparently too simple for the real road condition. Even those models built on a general network have not been tested and validated in the actual situation. Hai Yang did test his two-dimension model through simulating a small real road network in China; however, that road network has only 4 nodes. We still do not know whether the models work or not when they are implemented in a large-scale area in the real-world road network.

Different current regulation policies in the mathematical models

The most common way to regulate the private sector in the mathematical models is competition. However, few integrate the current regulation methods used in the practical projects into their model. In fact, whether the regulation method is effective or not, and to what extent, is a greater concern for the public and the policy-makers.

Less risk allocation considerations form the view of public

To promote the private investment in PPP toll road projects, many studies try to identify the risks of the private sector, and mitigate the private risk through suggesting some cost-sharing or traffic flow guarantee approaches. Unfortunately, few of them consider the risk allocation problem from the viewpoint of public. How should the public sectors make some agreements or suggest an approach to protect the public welfares and road users if any unforeseen events? How does the regulator allocate more risk to the private rather than to the road users? The answer to these questions is critical for the government and public agencies.

Above all, there are some gaps between the practice needs in the PPP toll road projects and the theoretical studies in this area. Future research is needed in this direction to narrow the gap. In that case, the policy-makers will have more powerful tools and better ideas to evaluate a PPP toll road project.

4. Methodology

4.1 Model

Lei Zhang built an equilibrium and evolutionary model of pricing, capacity choice, and ownership dynamics as summarized in his paper “Welfare and Financial Implications of Unleashing Private Sector Investment Resources on Transportation Networks”. (Lei Zhang, 2008). The model considers the evolution of price competition, capacity choice, and ownership dynamics over time. The private sector can decide if investing on a specific toll road, selecting the capacity level and determining the profit-maximum tolls on the road. The model was calibrated for the road network of Chicago metro area. And then, the model that was used to test the Chicago Skyway is an equilibrium and evolutionary model of pricing and capacity choice. However, the model was changed to a fixed ownership structure, which means the private sector cannot choose the candidate private toll road freely. The only road that may be operated by the private sector is the Skyway.

4.2 Test Scenarios

In this simulation, there are three test scenarios built to test the Chicago Skyway according to different road type (public or private) and regulation policies. They are the base scenario, current scenario, and the current-maximum scenario.

The Base Scenario

The first one is the base scenario, the situation of Chicago metro area without leasing the Chicago Skyway. In the base scenario, all the links and roads are operated and maintained by public in the future 50 years, from 2005 to 2055.

The Current Scenario

The second is the current scenario, which is the situation of the current Chicago metro area where the Skyway has been leased out to the private sector in the future 50 years. Under the regulation of the concession of the Skyway, the private sector can set the toll rates to maximize the profit as long as the toll rate is lower than the “ceiling toll rate” set in the regulation policy.

The Current-Maximum Scenario

The third scenario is the current-maximum scenario, which is essentially the same as the second scenario except the private operator can set the toll rates without the public regulation. In other words, the private sector can charge the road users as much as they want in order to maximize profit.

All the three scenarios are run with 50 iterations. Each one stands for one year so that we can get the predication results of the Skyway in the future 50 years. The base year is 2005 because it is the first year of the Skyway’s leasing lifespan. In the real world, the duration of Chicago Skyway lease is 99 years. However, a 99-year period is a long period to predict. For accuracy, we simply simulate the initial 50 years.

4.3 Data

The input data that was used to run the model is the historical traffic data of the Chicago Metro area and zoning data. They are from the Chicago Area Transportation Study (CATS), which was merged into the organization of Chicago Metropolitan Agency for Planning (CMAP).

5. Traffic and Welfare Effects Analysis of the Chicago Skyway

5.1 Traffic Impacts

Based on the simulation from 2005 to 2055, we can see the different impacts to the road users' travel pattern of the three test scenarios. According to Figure 5.1 and 5.2, we can see the private-operated Skyway (either with or without regulation) does not considerably change the Vehicle Hours Traveled (VHT) of the road network. The VHT trends of the three scenarios are almost the same. However, after the Skyway is leased to the private sector, the Vehicle Kilometers Traveled (VKT) of the road network increases. It is interesting to note that the total travel hours is consistent despite the leasing arrangement of the Skyway; however, the total travel distance increases if the Skyway was operated by the private sector. In that case, since the VKT of the network increases while the VHT almost remains relatively constant, we can say the privately-operated Skyway improves the level of service of the Chicago metro area network.

Another interesting thing we can find from the prediction results is the effects of the regulation of the private operator. Based on the simulation, we can find the regulation has few impacts to the traffic pattern, which means even without any "ceiling toll rates", the traffic demand of the whole network will not be impacted by the tolls.

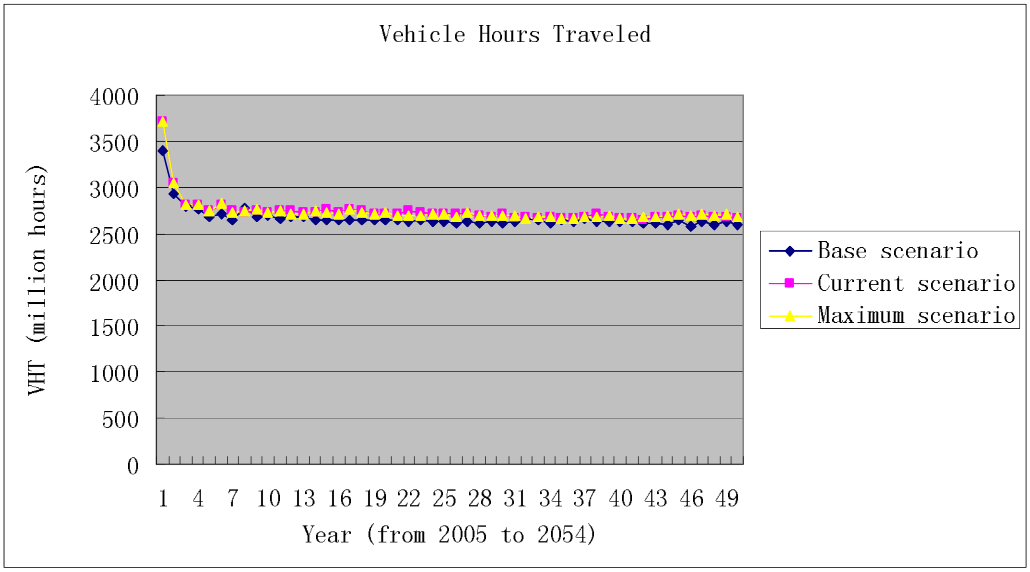


Figure 5.1 Vehicle Hours Traveled (VHT) of the Three Test Scenarios

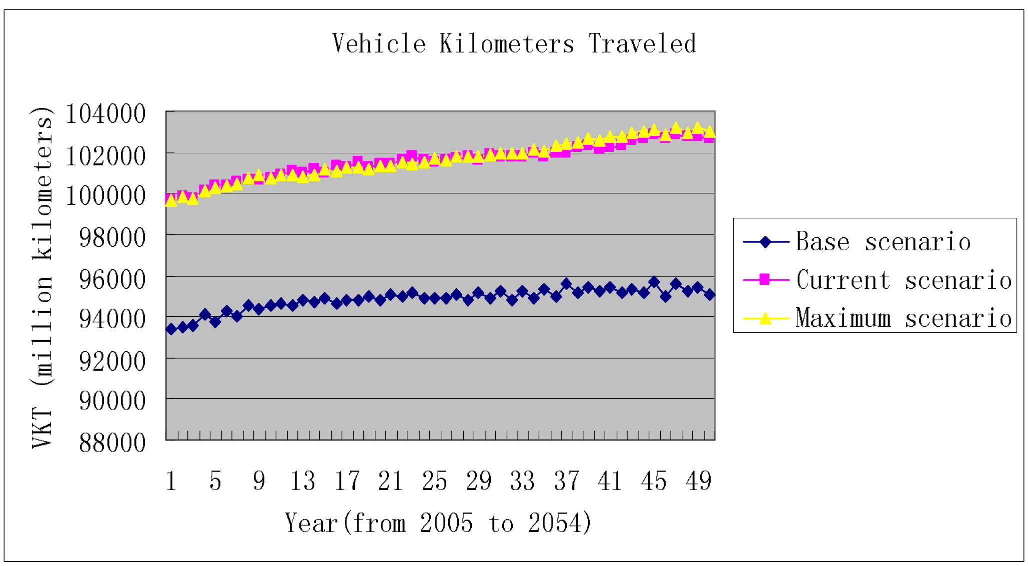


Figure 5.2 Vehicle Kilometers Traveled (VKT) of the Three Test Scenarios

5.2 Toll rates and private revenue

Since the base scenario is a pure public network scenario, only the current and current-maximum scenarios have the relationship to predict the results of tolls and private revenue. The toll rate of the base year (2005) is the actual toll rate of the Skyway in 2005. After that, the private operator will set optimal toll rates that will maximize the private revenue according to the previous year's traffic flow.

From Figure 5.3, in current scenario, the threshold (base year's toll rate) is $0.19 per kilometer, which is much higher than the following years'. Except for the threshold, the regulated optimal toll rates are in the range from $0.02 to $0.03 per kilometer. Obviously, the base year's toll rate is an outlier of the whole data set. We can see the relationship between toll rates and private revenue without the base year data in Figure 5.4. It demonstrates that the private sectors can maximize their revenue when they charge the road users of the Skyway $0.0298 per kilometer, under the regulation. On the other hand, from the perspective of the public agency, they should set the "ceiling toll rate" equals to, if not less than, $0.0298 per kilometer in order to regulate the private revenue.

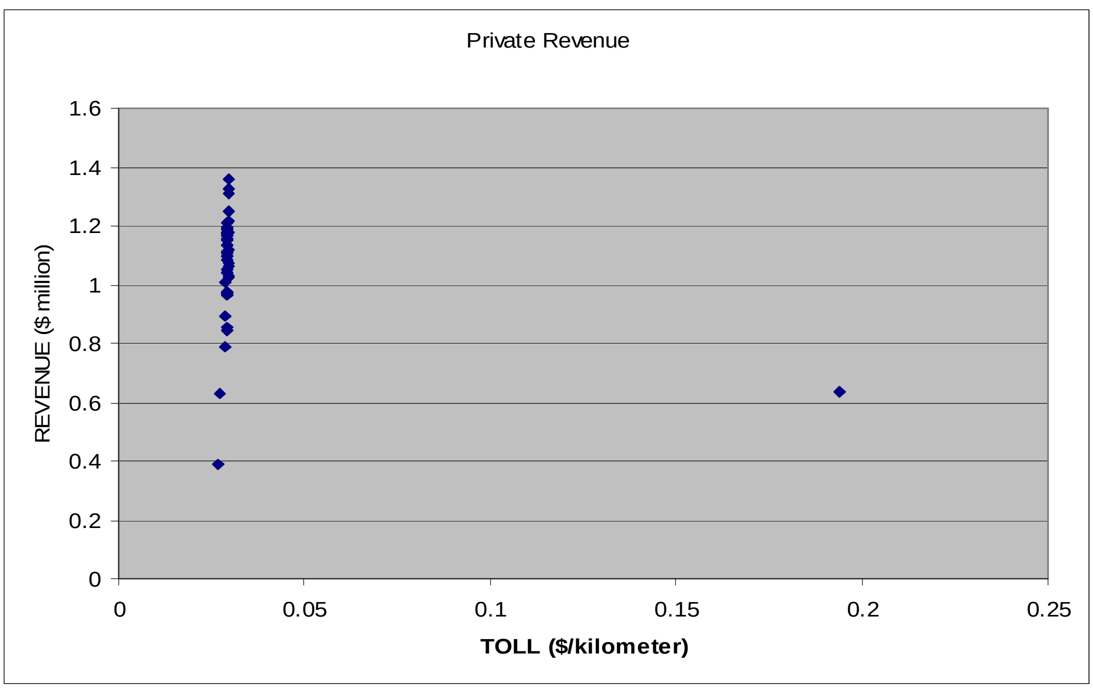
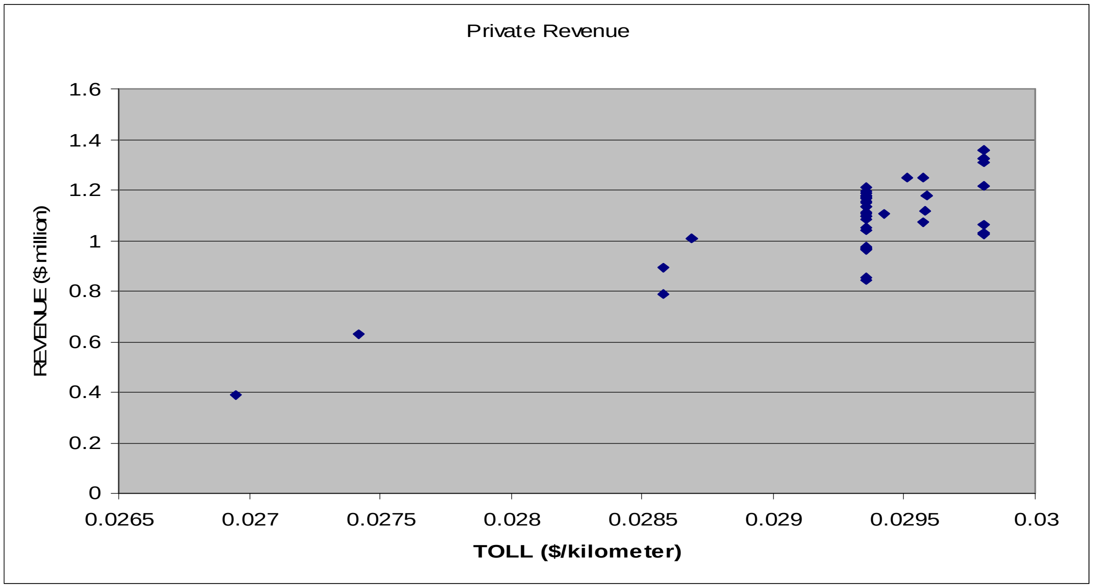


Figure 5.3 Relationship between Toll Rates and Private Revenue

(The current scenario)



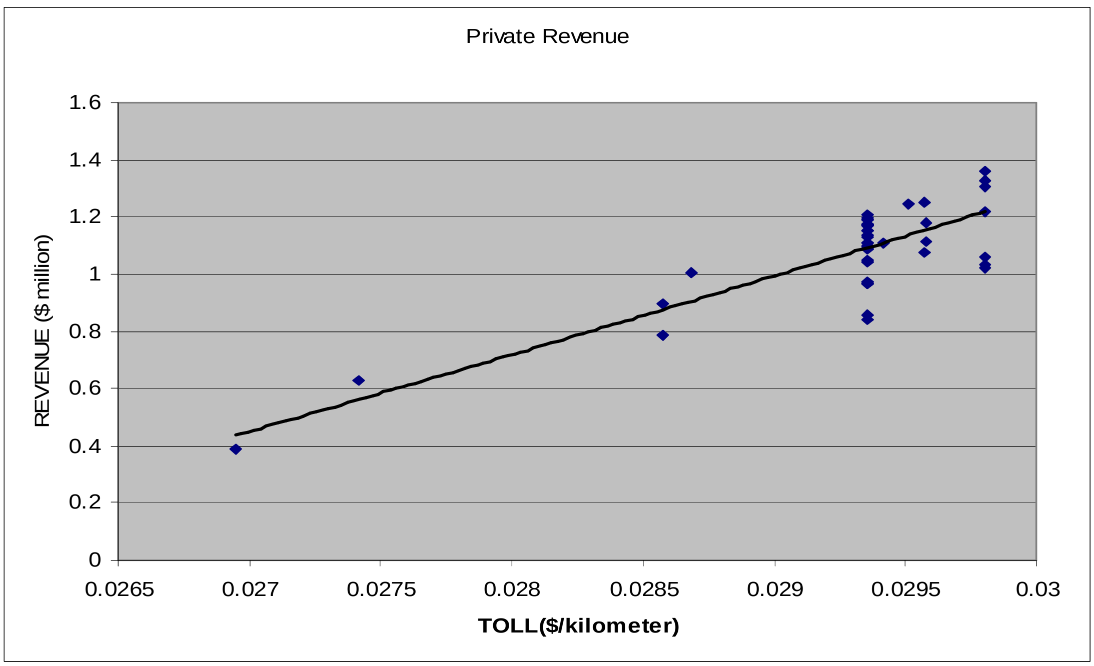


Figure 5.4 Relationship between Toll Rates and Private Revenue

(The current scenario & without the base year)

After the analysis of the current scenario results, we will see what will happen in the scenario without regulation. In the maximum scenario, the private operator can charge the road users as much they want. They still set the optimal toll rates based on the previous year's traffic data, but, without the regulation of any "ceiling toll rate." From

Figure 5.5, we can find the simulated toll rates are in the range from $0.03 to $0.09 per kilometer, except the base year's toll rate ($0.19 per kilometer). Similarly, the base year's data is the outlier of the whole data set.

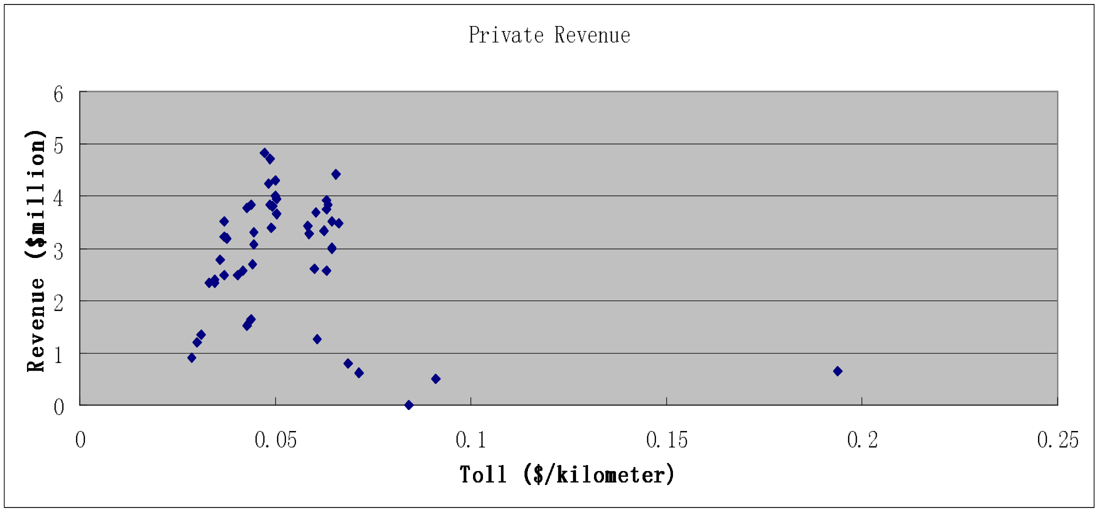
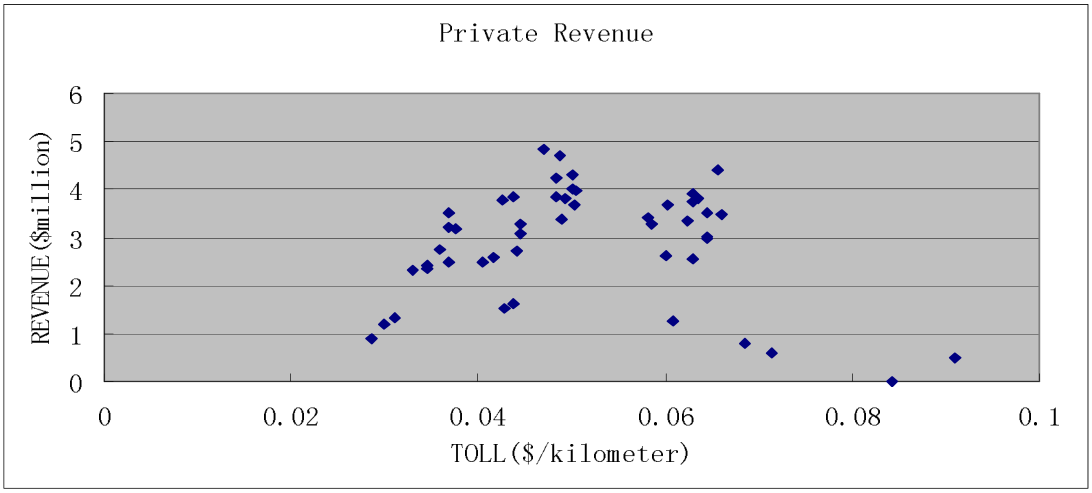


Figure 5.5 Relationship between Toll Rates and Private Revenue

(The current maximum scenario)

Without the base year's toll rate in the data set, according to the fourth order of the polynomial trend line, the maximum private revenue is achieved around the toll rate of $0.055 per kilometer. In addition, we can see the revenue trend line is quite unstable. The revenue is close to zero when the toll rate is approximately $0.085 per kilometer.



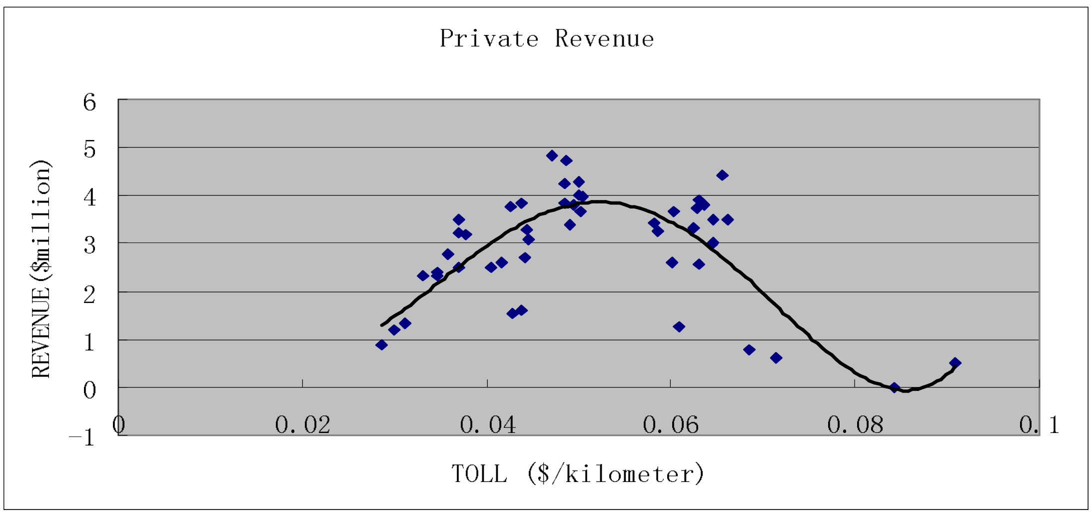


Figure 5.6 Relationship between Toll Rates and Private Revenue

(The current maximum scenario & without the base year)

From Figure 5.7, we can see the different trends between the revenues of the two scenarios. The private revenue ranges from $ 0.4 to $1.4 million in the current scenario, while the private revenue without regulation can ranges from $0.7 to $5 million. Obviously, the current-maximum scenario has the larger deviation. Basically, without regulation, the private sectors can receive revenue 2-3 times more than the scenario with regulation.

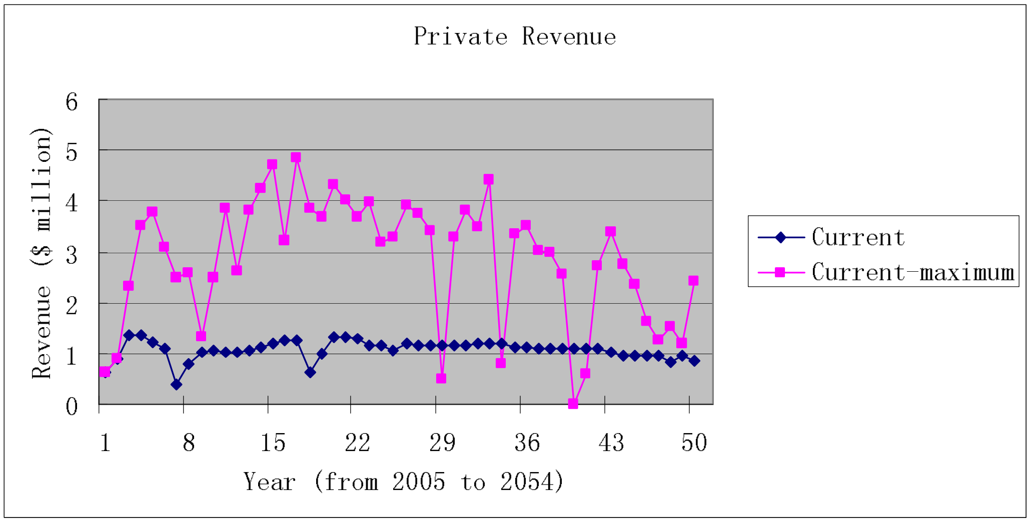


Figure 5.7 Private Revenue of the two scenarios

5.3 Net Social Benefit and Revenue of the Whole Network

Figure 5.8 and Figure 5.9 illustrate the simulation result of net social benefits for the entire Chicago metro area network in three different scenarios. Both the total revenue and the net social benefit increase after leasing out the Skyway. The increased net social benefits may be generated from less congestion and the improved Level of Service (LOS) for the entire network, as demonstrated in Section 4.1.1. The total revenue increases approximately $150 million through the Skyway project, and most of the increase is the revenue increase on the public roads, which proves the private-operated Skyway also improves the public network’s service.

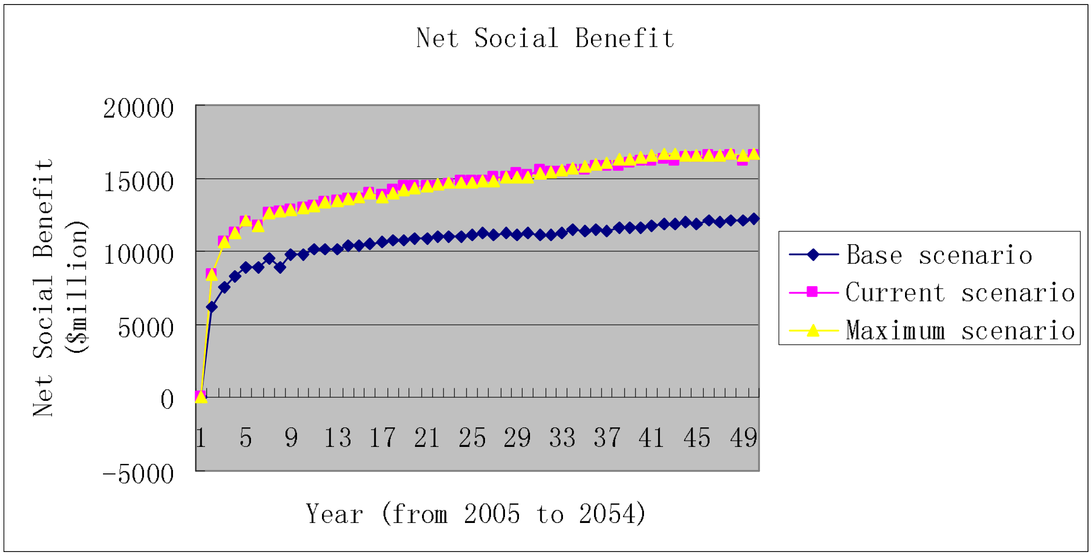


Figure 5.8 Net Social Benefits of the Three Test Scenarios

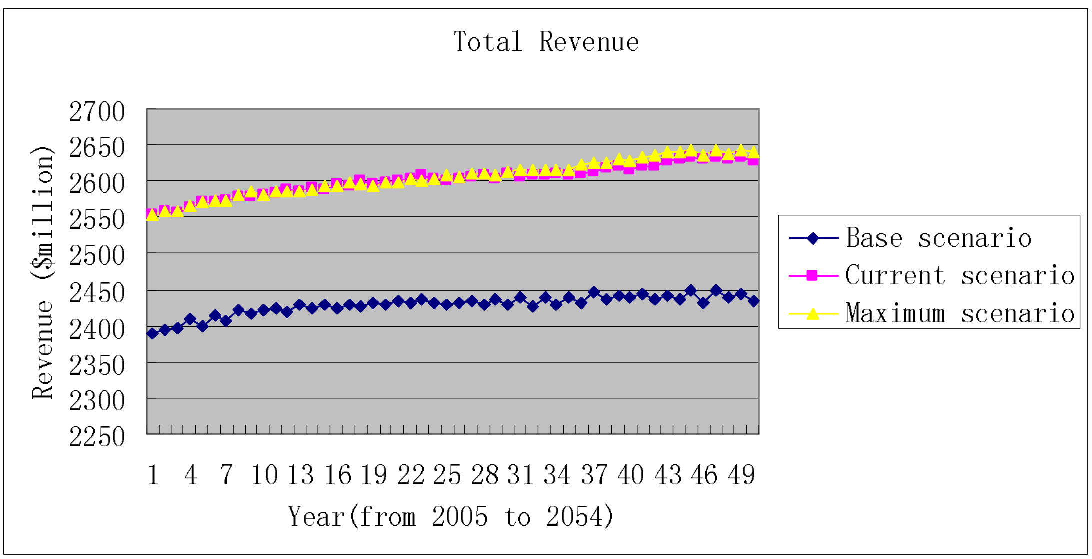


Figure 5.9 Total Revenue of the Whole Network of the Three Test Scenarios

Although the regulation affects the private revenue, it is interesting to note that without regulation, the Skyway has a similar welfare impact to the whole network with the impacts of the Skyway with regulation. The reason is, from the perspective of the whole network, the traffic demand is quite stable unless big land-use changes occur. However, the model we used in this paper does not integrate a land-use model and just sets a fixed annually traffic growth rate, which implies that the future years' traffic demand would not change significantly. Therefore, even if the private operator can charge the road users as much as they want, it would not hurt the traffic demand too much in the extent of the whole network. However, that does not mean we do not need the regulation policies for the private sector of the Skyway. In the real world, the land-use condition may change and the traffic demand may be effected. The private sector can charge the road users an unreasonable high toll rates and still make maximum profit under a large traffic demand or low-elastic demand, which is a situation that we do not want to see.

6. The "Non-compete" Clause Experimental Design

A "non-compete" clause is a hotly contested topic. After reviewing the current PPP toll road projects in the U.S., and the background of the "non-compete" clause, future study needs to be conducted to find out how the different forms of "non-compete" clauses affect the transportation system, and the impact on travel behaviors. In this section, several simulation scenarios are constructed to test the three categories of a "non-compete" clause and the situation without any "non-compete" clause, respectively. In each type of "non-compete" clause test scenario, we will try to find out how the clause parameters (area, period, reduction of the posting speed) affect the simulation results (VMT, private profit, public welfare).

6.1 The Impact of "Non-compete" Clause to the Three Parties

Obviously, the "non-compete" clause will affect the transportation system and the different sectors that are involved. The private sector, public authorities, and the road users are the three main parties that will be affected by the "non-compete" clause.

6.1.1 The Private Sector

The private sector will be the main beneficiary of the "non-compete" clause. Without the "non-compete" clause, one of the main risks the private sector has to consider is the uncertainty of toll revenue of the PPP toll road, which is controlled by the uncertain traffic demand. If the toll rate is set too high, the road users may take the parallel freeway instead of paying the toll. However, if the private operator sets a low toll rate to attract the traffic, they have to take the risk that the low rate cannot assure the profit. For this reason, the private sector tries to add the "non-compete" clause in the PPP toll road concessions or agreements. Obviously, those “non-compete” clauses are to protect the private revenue. Under the “non-compete” clause, the private sector can assure the traffic demand in the target PPP toll road by limiting the capacity of the public roads system nearby. In that case, the road users have to suffer longer travel times and more congestion if they do not choose the toll road.

Undoubtedly, the private sector is attempting to maximize profit from the PPP toll road project. As discussed, the private sector situation shifts from maximizing the profit under uncertain traffic demand conditions to the certain traffic demand condition because of the “non-compete” clause. The total private profit equals to the total revenue minus the road facility costs, which may include the construction costs, maintenances costs, and operation costs. Additionally, under some types of “non-compete” clause, the private sector can get some revenue compensation from the public entity if any there are any new road projects in specific area.

$$P = \sum_a \tau^a f^a - C_{\mathrm{Pr}i} + \sum \tau^a (f_0^a - f^a) \qquad \text{(Eq 6.1)}$$

P: The total private profit;

$C_{\mathrm{Pr}i}$: The private road facility costs;

τ^a : The toll rate of the toll road on year a;

f^a: The actual traffic flow of the toll road on year a;

f_0^a: The projection traffic flow of the toll road without any new road projects;

In the Equation 6.1, the first term is the actual toll revenue of the PPP toll road, the second term is the toll road’s facility costs, and the third one is the public compensation if the public agency has any road projects. We can see that the third term does not depend on the private sector. So, the private sector will try to chase the maximum profit either by increasing the toll revenue or decreasing the costs, or both.

If the private sector wants to raise the toll revenue under the “non-compete” clause, they can just set a high rate if there is not a toll rates regulation policy. The “non-compete” clause will limit the capacity expansion of the public freeway system and lead to a worse congestion level on parallel public freeways. So, the travelers will endure the high toll otherwise they will have to suffer the congestion problems and take extra travel time on the parallel public freeways as the road users will choose a route with least costs (toll and travel time). Equitation 6.2 shows the total cost of the travelers.

$$C_{Tra} = \tau + V * T \qquad \text{(Eq 6.2)}$$

C_{Tra} : The total travel cost of road user;

V : Value of Time (VOT) of road user;

T : Travel time of the road user

τ : The toll rate

In practice, there are always some provisions in the concession to regulate the toll rates so that the private sector cannot set the rates as they wish. However, they can meet the toll rates “cap” which is set in the concession without worrying about the traffic demand. On the other hand, the private sector may decrease the operation or maintenances costs to maximize the profit. They may operate the toll road with some level of congestion. Under congested condition, the private sector increases their profit while increasing the road users’ travel costs. As long as the total travel cost of the toll road is larger than the parallel freeway’s, the road users will still choose the toll road.

There is another situation. If the total traffic demand is much lower than the total roadway system capacity (including the toll road and parallel freeway system), a very rare situation in the current projects in the U.S., the road users will not endure the toll rates of the PPP toll road even if under a “non-compete” clause. In this case, even without an upgrade or newly-constructed freeway, the public can tolerate the traffic flow without too much congestion. According to the road users’ utility theory, the road users will choose the public road to minimize the total travel costs. However, as indicated above, the growing traffic demand will always overload the freeway system without an upgrade. As a result, this assumption is rare in the real world. .

6.1.2 The Public Authorities

It is difficult to define whether the public authorities will gain or lose through the “non-compete” clause. With the “non-compete” clauses, undoubtedly, the private investors are more willing to get involved into the PPP toll road projects because of the assurance of the travel demand in the toll road. It is helpful to address the public capital shortfall issue in the transportation facility. However, the “non-compete” clause limits the future improvement of the public freeway system or even lowers the capacity of the existing public road during a specific period. Obviously, it is a trade-off. The public authorities attract the private investment at the cost of giving up the right to upgrade their roads or to permit decreasing capacity of the existing freeways. So, the “non-compete” clauses may result in lower efficiency and bigger congestion problems on the public freeway system, such as the example of SR 91. Even under the limited “no new construction/ upgrade” clause, in which the public authorities can build some new roadways, the public sector still has to afford some additional costs to compensate the loss of the private revenue. Due to the extra costs, it may prohibit the new freeway construction projects even if the public freeway system suffers congestion problem.

With the limited funds, the public authorities have to accept the “non-compete” clause in order to attract the private investment in the transportation infrastructure projects and supplement the shortfall of public funds. However, in order to protect the public interests and maximize the public welfare, some additional provisions related to the "non-compete" clauses in the PPP toll road projects tries to protect the public agencies and road users. For instance, the termination provision related to the "non-compete" clause in the Pocahontas Parkway's leasing concession. The related termination provision assures that the private sector needs to operate the toll road efficiently, otherwise the "non-compete" clause will become void and the public will take back the right to upgrade the public freeway system [Tollroadsnews, 2006]. The related provision ensures that the private sector cannot raise their profit by keeping the toll road a congestion situation. It protects the public interest and the road users.

The "non-compete" clause may also stimulate the public agencies to develop the public transit system. As the congestion becomes worse and the public cannot expand the freeway system capacity to satisfy the growing demand, the public may try to develop the public transit to address the congestion issue.

6.1.3 Road Users

The local taxpayers are the absolute losers because of those "non-compete" clauses. They paid the taxes that are supposed to be used to build, expand, rehabilitate, and maintain the public road system. However, the "non-compete" clause may stop the road improvement projects, or even decrease the capacity of the existing roads. The local taxpayers have to pay more for travelling either in the form of extra travel time on the public road, or in the form of money on the PPP toll road.

Depending on the different features like trip purposes or income levels, the road users will have different VOT so that they will have different route choice between the PPP toll road and the parallel public freeway. The travelers with high income or high value of time, for instance, commuting to work or a job interview, are more likely to choose the PPP toll road and pay the toll rates in order to save some extra travel time. The travelers with low income or low value of time may have more preference to the public roads to avoid the toll rates in the PPP road. By minimizing the total travel cost, the road users will make their route choices under utility maximization theory.

In two cases that the road users who traveling on the PPP toll road will certainly be losers because of the “non-compete” clause. First, since eliminating the “competitive power” of the parallel freeway, and if there is no reasonable regulation policy to limit the private toll rates, the private sector will over charge a lot on the road users. Second, if the travel demand on the PPP toll road is higher than its capacity or the private sector keeps the toll road with some level of congestion, the travelers will suffer congestion in addition to the toll. For example, in Virginia, to avoiding the second case, the Virginia Department of Transportation (VDOT) added an additional termination provision of the “non-compete” clause in the Pocahontas Parkway’s leasing concession. The “non-compete” clause will be void if the private sector cannot address the congestion problem within a specific time period, if any. The additional termination provision protects the road users and the public’s interests.

Additionally, besides the change of route choice, the “non-compete” clause may change some other travel behaviors of the road users. Because of the congestion in the public freeway system caused by the “non-compete” clause, the road users may change their time of travel. In order to avoid travelling during peak hours, they may give more preference to driving during non-peak hours. The “non-compete” clause may decrease the trip frequency and increase the trip chaining. Drivers are more likely to link several trips together to decrease the times of paying the toll or be delayed by road congestion. People may be more willing to carpool or take public transit, if the carpool or transit can have some discount in the toll road or there is an HOV lane. The “non-compete” may also shift the land use. With the high toll rates on the toll roads and worse congestion, the location of the commercial firms may move to be close to their employees, suppliers, and customers. The households may move in order to have easier access to their employment, shopping and schools, or they may even move out of this area entirely to avoid the toll and congestion.

Above all, the private sector will gain from the “non-compete” clause since the “non-compete” clause assures the traffic in the PPP toll road unless the traffic demand is pretty low so that the parallel public freeways have the same travel time, or acceptably less than the toll road’s. The local taxpayers will be losers because the public roads in their area cannot be upgraded, and they need to afford the toll rates on the toll road or the extra travel time on the public freeway. The other road users may shift their route choices based on their social-demographic features, and the trip frequencies will decrease and the land use may also be affected by the “non-compete” clause. The public may suffer the lower efficiency of the public freeway system; however, they also can set some additional provisions related to the “non-compete” clause to protect the public interests.

6.2 Experimental Design

Based on the three different categories of “non-compete” clause, we developed four test scenarios: one base scenario without any “non-compete” clause and three test scenarios for each different “non-compete” clause. We can compare the different simulation scenarios’ results to find out the different types of “non-compete” clause’s impacts to the public welfare, private profit, and the road users’ behaviors.

Base Scenario

This base scenario is the condition without any “non-compete” clause. In this simulation scenario, the public authorities can use the public fund to construct new roads or improve any existing highway system near the PPP toll road, without any limitation or compensation, during the concession term. Its simulation result can be used to compare with other different scenarios' to analyze the impacts of different categories of "non-compete" clauses.

Scenario 1: Rigid "No New Construction/Upgrade" Clause

This scenario tests the condition with the first "non-compete" clause - rigid "no new construction/upgrade" clause. Under this clause, the public cannot build any new roads or upgrade the existing ones during a specific period. In this simulation scenario, we will test this sort of "non-compete" clause with different "non-compete" terms and "non-compete" areas. We are going to test nine sub-scenarios. Within 1.5-mile, 3-mile, and 10-mile of the target PPP toll road respectively, the public cannot have any road projects within 10 years, or 15 years, or during the whole term (30 years), as shown in Table 6.1.

Table 6.1 Nine Sub-Scenarios of the Test Scenario 1

	within 10 years	within 15 years	within 30 years
within 1.5-mile area	X	X	X
within 3-mile area	X	X	X
within 10-mile area	X	X	X

Note: The "non-compete" area is defined as the area with a certain radius. In this area, all the freeways paralleled to the PPP toll road will be regulated under the "non-compete" clause.

Scenario 2: Limited "No New Construction/ Upgrade" Clause

Scenario 2 will test the impacts of limited "no new construction/upgrade" clause to the freeway system. Under the scenario, the public can build new freeways or expand any existing roads. However, the public will compensate the private sector for the revenue loss led by their road projects within a specific area. We can use the four-step model to estimate the projection travel demand of the toll road without the newly-constructed freeways or existing roads' expansion projects. Then we can use the toll rates to multiply the difference between the projection demand and the actual demand of the toll road to calculate the private revenue loss. According to different "non-compete" areas, we are going to test three sub-scenarios: limited "no new construction/upgrade" clause within 1.5-mile area, within 3-mile area, and within 10-mile area.

- **Scenario 3: Lower Posting Speed of Parallel Public Roads**

In test scenario 3, the speed limit of the public roads nearby the PPP toll road will decrease. Depending on how long the lower speed limit works, how much the speed limit decreases, and how many public roads' speed limits will decrease, we will have eight sub-scenarios as shown in Table 6.2.

Table 6.2 Eight Sub-Scenarios of the Test Scenario 3

Public roads within 1.5-mile area		
	decrease 10MPH	decrease 15MPH
5 years	X	X
10 years	X	X
Public roads within 3-mile area		
	decrease 10MPH	decrease 15MPH
5 years	X	X
10 years	X	X

Note: The "non-compete" area is defined as the area with a certain radius. In this area, all the freeways paralleled to the PPP toll road will be regulated under the "non-compete" clause.

The program for testing the "non-compete" clause is ready and attached in the Appendix D. [Note: Due to problems beyond my control, I was unable to finish the "non-compete" clause's experiment.] Future research can be conducted based on the model and the test simulation scenarios that were used in this paper to test the impacts of different "non-compete" clause.

7. Conclusions and Recommendations

In order to relieve the public transportation financial problem, the PPP mode will still be a trend in the near future in the United Sates. After review of the current practical PPP toll road projects in the United States, the status of academic research in this area, and the gap between the practices and the theoretical study, we already have a general idea about the development situation and current issues of the PPP toll roads in the United Sates. Therefore, future study interests in PPP toll roads are suggested to focus on those gaps between the research and practical needs. In that way, we can apply the analytical results from theoretical studies in the practical decision-making process to help those decision-makers to make a wise choice when facing a PPP toll road project.

The simulation of the Chicago Skyway in this paper estimates that during the period from 2005 to 2055, the level of service of the whole Chicago metro area network would be improved and the total revenue of the whole network would increase if the Skyway is private-operated, irrespective of whether there are regulation policies or not. Under the "ceiling toll rate" regulation, the private sector can achieve the maximum revenue when the toll rate equals to the larger number of the "ceiling toll rate" and $0.0298 per kilometer. Without the "ceiling toll rate" regulation, the private operator can receive maximum toll revenue when the toll rate is $0.055 per kilometer, according to the simulation results. There are similar welfare and traffic impacts, to the whole network, of the Skyway both with and without regulation. It does not mean that we do not need to regulate the private operator. It occurs because the model does not integrate the land-use module and the traffic demand for the whole network is pretty stable. Additionally, the model uses homogeneity assumption that assumes all the travelers have the same VOT. Finally, the model just uses the average daily traffic rather than taking into account the peak hour traffic flow. In future studies, we need to improve the model to make it closer to the real-world situation.

The non-compete clause is always a hot debate in the PPP toll road area. In order to find out how those different “non-compete” clauses affect the network and the travel behaviors, we designed an experiment and wrote an extra program for testing the “non-compete” clause in the model. Due to a number of issues, we were not able to finish the simulation for this paper. The experiment and simulation should be completed in a future study.

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Appendix

Appendix A Maximum Toll Rate Setting

1. Indiana Toll Road

Maximum Toll Rates setting for Indiana Toll Road

<table>
<tr><th rowspan="2">Class</th><th colspan="6">Toll Rate</th></tr>
<tr><th>Until March 31, 2007</th><th>April 1,2007 - March 31, 2008</th><th>April 1,2008 - March 31, 2009</th><th>April 1,2009 – June 30, 2010</th><th>June 31, 2010 – June 30, 2011</th><th>After June 30, 2011</th></tr>
<tr><td>Two - axle</td><td>$8.00</td><td>$8.00</td><td>$8.00</td><td>$8.00</td><td rowspan="6">The toll rate on June 30, 2010 is permitted to increase the maximum toll levels by the greater of (A) 8.2% or (B) the percentage increase compounded annually of the Index or Per Capita Nominal GDP, whichever is greater, measured from each of (i) January 1,2006 to December 31,2006, (ii) January 1,2007 to December 31, 2007, (iii) January 1,2008 to December 31, 2008 and (iv) January 1,2009 to December 31, 2009.</td><td rowspan="6">The toll rate for all class vehicles is permitted to increase the maximum toll levels by the greater of (a) two percent (2%) or (B) the percentage increase of the Index or Per Capita Nominal GDP, whichever is greater, measured from January 1 to December 31 for the calendar year immediately preceding the Tolling Measurement Date.</td></tr>
<tr><td>Three - axle</td><td>$9.20</td><td>$9.90</td><td>$10.70</td><td>$11.77</td></tr>
<tr><td>Four - axle</td><td>$13.78</td><td>$17.40</td><td>$21.01</td><td>$24.63</td></tr>
<tr><td>Five - axle</td><td>$17.90</td><td>$22.60</td><td>$27.30</td><td>$32.00</td></tr>
<tr><td>Six - axle</td><td>$21.04</td><td>$26.56</td><td>$32.08</td><td>$37.61</td></tr>
<tr><td>Seven - axle or more</td><td>$39.06</td><td>$49.32</td><td>$59.57</td><td>$69.83</td></tr>
</table>

<table>
<tr><th rowspan="2">Class</th><th colspan="6">Through Trip Per Mile Rate (c/Mile)</th></tr>
<tr><th>Until March 31, 2007</th><th>April 1,2007 - March 31, 2008</th><th>April 1,2008 - March 31, 2009</th><th>April 1,2009 – June 30, 2010</th><th>June 31, 2010 – June 30, 2011</th><th>After June 30, 2011</th></tr>
<tr><td>Two - axle</td><td>5.10</td><td>5.10</td><td>5.10</td><td>5.10</td><td rowspan="6">The toll rate on June 30, 2010 is permitted to increase the maximum toll levels by the greater of (A) 8.2% or (B) the percentage increase compounded annually of the Index or Per Capita Nominal GDP, whichever is greater, measured from each of (i) January 1,2006 to December 31,2006, (ii) January 1,2007 to December 31, 2007, (iii) January 1,2008 to December 31, 2008 and (iv) January 1,2009 to December 31, 2009.</td><td rowspan="6">The toll rate for all class vehicles is permitted to increase the maximum toll levels by the greater of (a) two percent (2%) or (B) the percentage increase of the Index or Per Capita Nominal GDP, whichever is greater, measured from January 1 to December 31 for the calendar year immediately preceding the Tolling Measurement Date.</td></tr>
<tr><td>Three - axle</td><td>5.90</td><td>6.30</td><td>6.80</td><td>7.50</td></tr>
<tr><td>Four - axle</td><td>8.80</td><td>11.10</td><td>13.40</td><td>15.70</td></tr>
<tr><td>Five - axle</td><td>11.40</td><td>14.40</td><td>17.40</td><td>20.40</td></tr>
<tr><td>Six - axle</td><td>13.40</td><td>16.90</td><td>20.40</td><td>24.00</td></tr>
<tr><td>Seven - axle or more</td><td>24.90</td><td>31.40</td><td>37.90</td><td>44.50</td></tr>
</table>

Note: Source from http://www.in.gov/ifa/tollroad.html.

2. Chicago Skyway

Maximum Toll Rates setting for Chicago Skyway

Toll Regulation Term	Maximum Toll rate
2005-2008	$2.50 for 2-axles; $1.20 per axle for other vehicles
2008-2011	$3.00 for 2-axles; $1.80 per axle for other vehicles
2011-2013	$3.50 for 2-axles; $1.80 per axle for other vehicles
2013-2015	$4.00 for 2-axles; $3.00 per axle for other vehicles
2015-2017	$4.50 for 2-axles; $3.60 per axle for other vehicles
2017-2103	$5.00 for 2-axles; $4.20/axle plus an annual increase of the greater of two different measures of inflation - CPI or GDP/person - and 2%, for other vehicles

Note:

1. There is also a provision that if the former regulation term's toll rates for any vehicle class adjusted for inflation are greater than the nominal rates of the ones in the next regulation term, then the greater inflation adjusted rates will become the cap.
2. Note : Source from http://www.chicagoskyway.org/tolls/

3. Virginia Route 895 (Pocahontas Parkway)

Maximum Toll Rate Setting for Pocahontas Parkway (Route 895)

Period	Mainline Plaza	Laburnum Avenue Ramp Plaza
January 2006-31 December 2007	$2.25	$0.75
January 2008-31 December 2010	$2.75	$1.00
January 2011-31 December 2012	$3.00	$1.25
January 2013-31 December 2013	$3.25	$1.50
January 2014-31 December 2014	$3.50	$1.75
January 2015-31 December 2015	$3.75	$2.00
January 2016-31 December 2016	$4.00	$2.25
After 2016	The maximum toll increase will be the greater of the increase in Real GDP, CPI or 2.8%.	

Note: Toll levels are for 2-axle vehicle only. Multi axle vehicles are tolled on the basis of an additional $1.00 for each axle above

4. Dulles Greenway

Maximum Toll Rate Setting for the Dulles Greenway

From date	Base 2-axle toll	Congestion management toll (applicable only to weekday traffic in peak period & direction)
January 1, 2009	$3.40	$4.00
July 1, 2010	$3.70	$4.50
January 1, 2012	$4.00	$4.80

Appendix B Toll Rates of the PPP Toll Roads in the US

Current Toll Rates of the PPP Toll Roads in the US

PPP toll roads	Length (mile)	2-axle vehicle Through trip toll ($)	per mile rate (c/mile)
Chicago Skyway	7.8	3.00	38.46
Indiana Toll Road	157	4.65	2.96
Foley Beach Express	13.5	3.00	22.22
Dulles Greenway	14	3.50 for weekday, 3.30 for weekend	25.00 for weekday, 23.57 for weekend
South Bay Expressway	12.5	3.75	30.00
The Pocahontas Parkway	8.8	3.00	34.09
Texas State Highway 130	49	2.00	4.08
E-470 Tollway	47	11.75	25.00

1. Chicago Skyway

Toll rates of Chicago Skyway (effective in 2006)

	Toll Rate	
	Peak times (4 am to 8 pm)	Off-Peak Times (8 pm to 4 am)
2-axle	$2.50	$2.50
3-axle	$5.10	$3.60
4-axle	$6.80	$4.80
5-axle	$8.40	$6.00
6-axle	$10.10	$7.20
7-axle or more	$11.80	$8.40

Source: From http://www.chicagoskyway.org/tolls/

This toll rates is still effective in 2007, but the toll rates will be changed in January 2008.

Toll rates of Chicago Skyway (effective from January 1st, 2008)

	Toll Rate	
	Peak times - 4 a.m. to 8 p.m.	Off-Peak Times - 8 p.m. to 4 a.m.
2-axle	$3.00	$3.00
3-axle	$7.60	$5.40
4-axle	$10.10	$7.20
5-axle	$12.60	$9.00
6-axle	$15.20	$10.80
7-axle or more	$17.70	$12.60

Source: From http://www.chicagoskyway.org/news/article.asp?ARTICLE_ID=7

2. Indiana Toll Road

Toll rates of Indiana Toll Road (before April, 2006)

	Toll Rate for the whole 157- mile	Per Mile Rate (c/Mile)
2 - axle	$4.70	3.0
3 - axle	$8.90	5.6
4- axle	$11.20	7.1
5- axle	$14.60	9.3
6- axle	$17.10	10.9
7 - axle or more	$31.80	20.2

Source: From http://www.in.gov/ifa/tollroad.html

Toll rates of Indiana Toll Road (effective in 2007)

	For the whole 157-mile		For the summation of each separate section	
	Toll Rate	Per Mile Rate (c/Mile)	Toll Rate	Per Mile Rate (c/Mile)
2 - axle	$4.65	2.96	$5.90	3.76
3 - axle	$10.00	6.37	$14.50	9.24
4- axle	$17.50	11.15	$24.50	15.61
5- axle	$22.50	14.33	$31.75	20.22
6- axle	$26.50	16.88	$37.50	23.89
7 - axle or more	$49.25	31.37	$69.00	43.95

Source: From https://www.getizoom.com/tollRatesRedirect.do

3. Foley Beach Express

Toll rates of Foley Beach Express (effective in 2006)

Class	Toll rate
2-axle	$2.00
3-axle	$3.00
4-axle	$4.00
5-axle	$5.00
6-axle	$6.00
more than 6-axle	$6.00+$1.00 for each additional axle

Toll rates of Foley Beach Express (effective in 2007)

Class	Toll rate
2-axle	$3.00
3-axle	$4.00
4-axle	$5.00
5-axle	$6.00
6-axle	$7.00
more than 6-axle	$7.00+$1.00 for each additional axle

Source: From http://www.foleybeachexpress.com/default.aspx?p=rates

4. Dulles Greenway

Toll rates effective of Dulles Greenway (effective in 2006)

	Toll Rates							
	Weekday				Weekend			
	Cash/ Credit Card		Smart- Tag/EZ-Pass		Cash/ Credit Card		Smart- Tag/EZ-Pass	
	2-axle	3-axle or more	2-axle	3-axle or more	2-axle	3-axle or more	2-axle	3-axle or more
Dulles Toll Road	$3.20	$6.40	$3.20	$6.40	$3.00	$6.00	$3.00	$6.00
MLB - Rt 28	$2.70	$5.40	$2.70	$5.40	$2.50	$5.00	$2.50	$5.00
Route 606	$2.70	$5.40	$2.70	$5.40	$2.50	$5.00	$2.50	$5.00
Route 607	$2.70	$5.40	$2.70	$5.40	$2.50	$5.00	$2.50	$5.00
Route 772	$2.00	$4.00	$1.55	$3.10	$2.00	$4.00	$1.55	$3.10
Claiborne Parkway	$2.00	$4.00	$1.55	$3.10	$2.00	$4.00	$1.55	$3.10
Route 659	$2.00	$4.00	$1.55	$3.10	$2.00	$4.00	$1.55	$3.10

Toll rates of Dulles Greenway (effective October 1, 2007)

	Toll Rates									
	Cash/ Credit Card					Smart- Tag/EZ- Pass				
	2-axle	3-axle	4-axle	5-axle	6+ axle	2-axle	3-axle	4-axle	5-axle	6+ axle
Weekday										
Dulles Toll Road	$3.50	$6.75	$8.50	$10.25	$12.00	$3.50	$6.75	$8.50	$10.25	$12.00
MLB - Rt 28	$3.00	$6.00	$7.50	$9.00	$10.50	$3.00	$6.00	$7.50	$9.00	$10.50
Route 606	$3.00	$6.00	$7.50	$9.00	$10.50	$3.00	$6.00	$7.50	$9.00	$10.50
Route 607	$3.00	$6.00	$7.50	$9.00	$10.50	$3.00	$6.00	$7.50	$9.00	$10.50
Route 772	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45
Claiborne Parkway	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45
Route 659	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45
Weekend										
Dulles Toll Road	$3.30	$6.35	$8.00	$9.65	$11.30	$3.30	$6.35	$8.00	$9.65	$11.30
MLB - Rt 28	$2.80	$5.60	$7.00	$8.40	$9.80	$2.80	$5.60	$7.00	$8.40	$9.80
Route 606	$2.80	$5.60	$7.00	$8.40	$9.80	$2.80	$5.60	$7.00	$8.40	$9.80
Route 607	$2.80	$5.60	$7.00	$8.40	$9.80	$2.80	$5.60	$7.00	$8.40	$9.80
Route 772	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45
Claiborne Parkway	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45
Route 659	$2.30	$4.60	$5.75	$6.90	$8.05	$1.85	$3.70	$4.60	$5.55	$6.45

Source: From http://www.dullesgreenway.com/cgi-bin/dgtollsched.cfm?home=dg

5. South Bay Expressway (SR 125)

Toll rates of South Bay Expressway (effective in 2007)

	Toll Rates	
	Cash	FasTrak
2-axle	$3.75	$3.50
3-axle	$7.50	$7.00
4-axle	$7.50	$7.00
5-axle	$11.25	$10.50

Source: From http://www.southbayexpressway.com/tollwiz/index.php

6. The Pocahontas Parkway (Route 895)

Toll rates effective of Route 895 (effective in January 2006)

	toll rates			
	Mainline Plaza		Laburnum Avenue Ramp Plaza	
	using Smart Tag or E-ZPass	paying cash	using Smart Tag or E-ZPass	paying cash
2-axle	$2.00	$2.25	$0.50	$0.75
3-axle	$3.00	$3.00	$0.50	$0.75
4-axle	$4.00	$4.00	$0.50	$0.75
5-axle	$5.00	$5.00	$0.50	$0.75
6-axle or more	$6.00	$6.00	$0.50	$0.75

Source: From http://www.pocahontasparkway.com/toll.html

7. Texas State Highway 130

Toll rates of Texas State Highway 130 (effective in 2007)

	toll rates			
	Plazas		Ramps	
	using TxTag	paying cash	using TxTag	paying cash
2-axle	$1.35	$1.50	$0.45	$0.50
3-axle	$2.70	$3.00	$0.90	$1.00
4-axle	$4.05	$4.50	$1.35	$1.50
5-axle	$5.40	$6.00	$1.80	$2.00
6-axle or more	$6.75	$7.50	$2.25	$2.50

Source: From http://www.txtag.org/centex.php

8. E-470 Tollway

Toll rates effective of E-470 Tollway (effective in 2006)

	Toll rate for the entire E-470 (111.20 – mile)
2-axle	$11.75
3-axle	$23.50
4-axle	$35.25
5-axle	$47.00
6-axle	$58.75
7-axle	$70.50

8-axle	**$82.25**
9-axle	**$94.00**

Source: From http://www.e-470.com/Default.aspx?tabid=87

Appendix C Theoretical Models of the PPP Toll Roads

Review of the PPP Toll Roads' Theoretical Models

	Main Assumptions	Main Results	Suitable for the types of PPP toll roads
One Single Toll Road Models			
Charles et al (1997)	1. build a model just considering one single road without any parallel routes; 2. Just consider the options of building a new highway or upgrading the existing one; 3. No long-term loans	Private only make profit in metropolitan road projects or upgrades of interurban highway with high traffic potential or low construction costs	BOT
Gines de Rus et al (2004)	1. Build a model just considering one single road without any parallel routes; 2. Homogeneous road users	1. According to the model, the toll revenue can cover the maintenance and operation costs for sure, but whether can cover the investment cost depends; 2. variable term concession could help in the introduction of optimal toll road pricing	BOT or leasing roads
Wang et al. (2004)	1. Build a model just considering one single road without any parallel routes, but with some other competing transportation modes; 2. Heterogeneous road users; 3. constant travel time and fees	1. When the transit operator leading the fare decision, the transit service will be best; 2. When one private sector operate the transit and highway, the profit will be the highest; 3. The transit operator prefers to follow the highway operator to decide their fare and service frequency.	BOT or leasing roads
Two parallel routes in one OD pair			
Palma et al. (2000)	1. Build a model with two parallel routes; 2. Homogeneous road users; 3. Use queue-eliminating tolls plus initial tolls system to replace the	1. The higher efficiency gain will be achieved if the flat tolls are replaced; 2. The Nash equilibrium and Stackelberg scenarios get	BOT

	flat tolls system	most social surplus; 3. the private duopoly ownership regime will lead to highest efficiency gains if neither route has a dominant fraction of total capacity, and a private route parallel to a free access route will yield the most efficiency if the two routes have almost equal capacities.	
Tsai et al. (2003)	1.Build a model with two parallel routes; 2. Homogeneous road users.	1. The regulation has less power under the condition of low elastic demand; 2. The high private efficiency will lead to more welfare gain even under regulation.	BOT
Gronau (1997)	1. Build a model with two perfectly substitutable parallel routes (one private toll road and one free public road); 2. Homogeneous road users; 3. Varied road capacity	1. The profit-maximizing toll is higher than the optimal toll; 2. The smaller the elasticity of travel demand, the more congested the free alternative road.	BOT or leasing roads
Philip A. Viton (1995)	1. Build a model with two parallel routes (one private toll road and one free public road); 2. Homogeneous road users; 3. Varied road capacity	1. The private sector can guarantee profit especially in the urban highway scenario even under some reasonable regulation; 2. The profitability are more likely to fail in the intercity project, especially when the distance is long and traffic is light	BOT
Two-dimension models in general road networks			
Yang and Meng (2000)	1. Build a toll- capacity two-dimension model in general road networks; 2. Homogeneous road users	Induct the function to calculate the profit and optimal toll	BOT
Anthony et al. (2001)	1. Build a toll- capacity two-dimension model in general road networks;	1. Introduce a function to address the probability of achieve a desire profit to	BOT

	2. Homogeneous road users	know the risk of one specify project; 2. Get the function to calculate the optimal toll and optimal capacity for a specify project; 3. The capacity has a greater impact than toll to the finance feasibility.	
Yang et al. (2002)	1. Build a toll- capacity two-dimension model in general road networks; 2. Heterogeneous road users	The homogeneous users model may result in that the traffic flow and private profit been overestimated at lower toll, or underestimated at higher toll, and may also lead to over-investment on a BOT toll road.	BOT
Xiao, and Yang et al. (2006)	1. Build a toll- capacity two-dimension model in general road networks; 2. Neither the toll nor the capacity can affect the profit solely.	The private competition does not necessarily reduce the road congestion	BOT
three-dimensional model in general road network			
Lei Zhang (2006)	1. Build a three-dimensional model by adding time dimension in general road network; 2. The revenue will be used to expand the capacity of links with highest benefit cost ratios; 3. Homogeneous road users; 4. Fixed traffic growth rate in the future years	1. Most of the private profit comes from the net social benefit; 2. The parallel public free route can regulate the private revenue, sometimes, replacing the toll or capacity regulation.	BOT or leasing roads

Appendix D The Coding of the "Non-compete" Clause Experiment

```
import java.util.Vector;

public class Road{
    /*
      * LinkNumber: Index of link
      */
    public int LinkNumber;
    /*
      * index of original node
      */
    public int ONode;
    /*
      * index of destination node
      */
    public int DNode;
    /*
      *X,Y coordination of original and destinational node
      */
    public double Ox;
    public double Oy;
    public double Dx;
    public double Dy;
    /*
      * Whether this road can be updated with different limited distance
      */
    public boolean UpdateOne;
    public boolean UpdateTwo;
    public boolean UpdateThree;
    /*
      * Free-flow time of links
      */
    public double FFTime;
    /*
      * Link length
      */
    double length;
    /*
```

```
  * default constructor
  */
public Road()
{

}

/*
  *
  */
public Road(int _LinkNumber, int _ONode, int _DNode,
              double _Ox, double _Oy, double _Dx, double _Dy,
              boolean _UpdateOne, boolean _UpdateTwo, boolean _UpdateThree,
              double _FFTime, double _length, double _FFSpeed)
{
       this.LinkNumber = _LinkNumber;
       this.ONode = _ONode;
       this.DNode = _DNode;
       this.Ox  = _Ox;
       this.Oy = _Oy;
       this.Dx = _Dx;
       this.Dy = _Dy;
       this.UpdateOne = _UpdateOne;
       this.UpdateTwo = _UpdateTwo;
       this.UpdateThree = _UpdateThree;
       this.FFTime = _FFTime;
       this.length = _length;
}
/*
  * Links' distance function
  */
public double distance(Road r1, Road r2)
{
      double distance;
      double tmp1x = (r1.Ox + r1.Dx)/2;
      double tmp1y = (r1.Oy + r1.Dy)/2;
      double tmp2x = (r2.Ox + r2.Dx)/2;
      double tmp2y = (r2.Oy + r2.Dy)/2;
      distance = Math.sqrt((tmp1x-tmp2x)*(tmp1x-tmp2x) +
(tmp1y-tmp2y)*(tmp1y-tmp2y));
      return distance;
}
```

```
/*
 * lower the post speed of the public links
 */
public void updateFFTime(int speedReduce)
{
    this.FFTime = this.length/(this.length/this.FFTime - speedReduce);
}

public static void main(String[] args){

    /*******************************************/
    System.out.println("Test for Road Class");
    int currentSpeedReduce = 15; //change it as needed (10/15)
    double DistanceLimitOne = 1.5;
    double DistanceLimitTwo = 3.0;
    double DistanceLimitThree = 10.0;
    Vector EffectedRoadOne = new Vector();
    Vector EffectedRoadTwo = new Vector();
    Vector EffectedRoadThree = new Vector();
    int PublicLinkNumber = 1000; // change it according to the link file
    int PrivateLinkNumber = 1000; // change it according to the link file
    Road[] PubRoadDB = new Road[PublicLinkNumber];
    Road[] PriRoadDB = new Road[PrivateLinkNumber];
    int[]   AffactedRoad = new int[PublicLinkNumber];


    // read the information from other class
    for(int i = 1; i <= PublicLinkNumber; i++)
    {
        PubRoadDB[i] = new Road(); // need to read from other class
    }
    for(int i = 1; i <= PrivateLinkNumber; i++)
    {
        PriRoadDB[i] = new Road(); // need to read from other class
    }

    int flagOne = 0; //use to calculate the number of affected links by the
non-compete clause, with differetn distance limits, respectively
    int flagTwo = 0;
    int flagThree = 0;
    for(int i = 0; i < PublicLinkNumber; i++)
    {
```

```
        for(int j = 1;j <= PrivateLinkNumber; j++)
        {
            double d = PriRoadDB[j].distance(PubRoadDB[i], PriRoadDB[j]);
            if(d <= DistanceLimitOne)
            {
                flagOne++;
                EffectedRoadOne.add(PubRoadDB[i].LinkNumber);
            }
            if(d <= DistanceLimitTwo)
            {
                flagTwo++;
                EffectedRoadTwo.add(PubRoadDB[i].LinkNumber);
            }
            if(d <= DistanceLimitThree)
            {
                flagThree++;
                EffectedRoadThree.add(PubRoadDB[i].LinkNumber);
            }
         }
    }

    int method = 1; //method 1: non-upgrade; method 2: lower the posting speed
of public links
    if(method == 1)
    {
        for(int i = 0; i <= EffectedRoadOne.size(); i++)
        {
            PubRoadDB[((Integer)
EffectedRoadOne.elementAt(i)).intValue()].UpdateOne = false;
        }
        for(int i = 0; i <= EffectedRoadTwo.size(); i++)
        {
            PubRoadDB[((Integer)
EffectedRoadTwo.elementAt(i)).intValue()].UpdateTwo = false;
        }
        for(int i = 0; i <= EffectedRoadThree.size(); i++)
        {
            PubRoadDB[((Integer)
EffectedRoadThree.elementAt(i)).intValue()].UpdateThree = false;
        }
    }
    else if(method == 2)
```

```
        {
            for(int i = 0; i <= EffectedRoadOne.size(); i++)
            {
                PubRoadDB[((Integer)
EffectedRoadOne.elementAt(i)).intValue()].UpdateOne = true;
                PubRoadDB[((Integer)
EffectedRoadOne.elementAt(i)).intValue()].updateFFTime(currentSpeedReduce);
            }
            for(int i = 0; i <= EffectedRoadTwo.size(); i++)
            {
                PubRoadDB[((Integer)
EffectedRoadTwo.elementAt(i)).intValue()].UpdateTwo = true;
                PubRoadDB[((Integer)
EffectedRoadTwo.elementAt(i)).intValue()].updateFFTime(currentSpeedReduce);
            }
            for(int i = 0; i <= EffectedRoadThree.size(); i++)
            {
                PubRoadDB[((Integer)
EffectedRoadThree.elementAt(i)).intValue()].UpdateThree = true;
                PubRoadDB[((Integer)
EffectedRoadThree.elementAt(i)).intValue()].updateFFTime(currentSpeedReduce);
            }

        }



    }

}
```