MEASURING THE FINANCIAL EFFICIENCY OF PPP TOLL ROAD PROJECTS IN THE REPUBLIC OF KOREA: A DEA ANALYSIS

By

BYUN, Hyeri

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

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ABSTRACT

MEASURING THE FINANCIAL EFFICIENCY OF PPP TOLL ROAD PROJECTS IN THE REPUBLIC OF KOREA: A DEA ANALYSIS

By

Hyeri Byun

Analysis has been performed to document success and failure factors of the Public-Private Partnership (PPP) market in Korea to assist in establishing effective PPP policy. Since it is difficult to define success or failure based on one dependent variable or output, and to make identification of objective relationships between multiple inputs and outputs possible, Data Envelopment Analysis (DEA) has been used to measure the success of PPP road projects in Korea. The most significant difference setting this work apart from other papers using DEA is a focus on the financial aspects of PPP projects instead of the governmental perspective, viewing PPP projects as a type of Project Financing (PF) investment.

In this study, an input-oriented Banker, Chames and Cooper (BCC) model was used for analysis, and the input and output factors for DEA were as follows: input factors included operating cost, Amortization of Management and Operation Rights (AMOR), and interest expense, while output factors consisted of Cash Flow from Operating Activities (CFOA), traffic volume (annual average daily traffic), and sales.

Overall findings show that projects with a high efficiency score are characterized by a medium input level with a high level of output, and projects in the Seoul

metropolitan area or those receiving a higher ratio of MRG to sales tended to receive higher efficiency scores. Policy implications are as follows: The government needs to estimate traffic volume more carefully and thoroughly, especially when proceeding with new projects in local areas or non-Seoul metropolitan areas through the use of a periodical monitoring system for demand while also tightening up internal supervision over the authority in charge. Also, the government would do well to make a continuous effort to reduce the fiscal burden by altering the subsidy payment mechanism from MRG to MCC.

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Ⅰ. Introduction

The Private-Public Partnership (PPP) market in Korea has existed for about 20 years and is now entering a mature phase. However, evaluations of the PPP system and market are mixed, with both positive and negative assessments. Hence, it is warranted at this point to explore the current system to document success and failure factors by conducting a rigorous study to assist in establishing effective PPP policy, with the Korean system and market as a benchmark.

The most significant aspect differentiating this paper from others using Data Envelopment Analysis (DEA) is a focus on the financial aspects of PPP projects themselves instead of prioritizing the governmental point of view, approaching PPP projects as Project Financing (PF) investments.

Among numerous factors that influence success or failure, the location of projects (affecting demand), type of road (highly related to construction cost), and revenue subsidies (directly increasing sales) were chosen to improve the observation of effects. To be specific, three hypotheses were defined. First, Seoul metropolitan area projects were anticipated to be more efficient than those in non-Seoul metropolitan areas. Second, main road projects were anticipated to be more efficient than tunnel/bridge projects. Third, projects with Minimum Revenue Guarantee (MRG) payments were anticipated to be more efficient than projects without.

The primary purpose of this paper is to report the results of a quantitative study using DEA from a financial perspective to assess PPP road projects in the Republic of Korea. DEA was used since it offers a method to measure relative efficiency by estimating a producible set and boundary based on input and output data for each

Decision Making Unit (DMU) when multiple input and output factors exist. Calculating a relative efficiency score using several output factors was an attractive approach because it is otherwise difficult to identify objective relationships between inputs and outputs, given the challenge of characterizing production and unsuitability of parametric efficiency analysis for discussing the efficiency of the production function. On the other hand, DEA lacks the advantages of a functional method since it is not true that any assumption can be statistically validated and the relationship between inputs and outputs does not necessarily follow the form of a function. Nonetheless, the strengths were deemed to outweigh these drawbacks for the context of this study.

This paper is composed of four parts: Firstly, the PPP system in the Republic of Korea is examined and a literature review on success factors is presented. Secondly, DEA methodology is examined. After that, the results of a DEA assessment of each project are reported. The final section presents findings and discussion related to success factors and suggests a direction for future PPP policy.

Ⅱ. Theoretical Study and Literature Review

2.1 Overview of the PPP System in the Republic of Korea

1) Legal Framework for PPP

After the enactment of the Act on Promotion of Private Capital Investment in Social Overhead Capital in 1994, intended to induce an influx of private capital to build infrastructure facilities, the legal framework of the PPP system in the Republic of Korea was reformed and evolved to become more sophisticated and better promote PPP markets. The current hierarchy of legal arrangements for the PPP system is as follows: 1) the Act on Public-Private Partnerships in infrastructure (PPP Act), 2) presidential decrees such as the Enforcement Decree of the PPP Act, 3) the Basic Plan for PPP Projects by the Ministry of Strategy and Finance, and 4) guidelines for the implementation of PPP projects by the Korea Development Institution (KDI).

2) Eligible Types of PPP Projects

Under the current legal system, Build-Transfer-Operate (BTO), Build-Transfer-Lease (BTL), Build-Operate-Transfer (BOT), and Build-Own-Operate (BOO) are possible structures. Among PPP types, BTO and BTL are most common in the Republic of Korea. According to Article 3 of the Basic Plan for PPP Projects (2016), PPP types are defined as follows.

Table 1

Public–Private Partnership Types in the Republic of Korea

A PPP project may be implemented in any of the following forms pursuant to Article 4 of the Act:

1. BTO (Build-Transfer-Operate): A type of arrangement in which the ownership of an infrastructure facility vests in the central government or a local government upon completion (new establishment, enlargement, or improvement) of the facility, while the concessionaire is granted the right to manage and operate the facility for a specified period;
2. BTL (Build-Transfer-Lease): A type of arrangement in which the ownership of an infrastructure facility vests in the central government or a local government upon completion (new establishment, enlargement, or improvement) of the facility, while the concessionaire is granted the right to manage and operate the facility for a specified period, but the central government or local government leases the facility for the period stipulated in the concession agreement to use and benefit from the facility;
3. BOT (Build-Operate-Transfer): A type of arrangement in which the ownership of an infrastructure facility belongs to the concessionaire during a specified period after completion;
4. BOO (Build-Own-Operate): A type of arrangement in which the ownership of an infrastructure facility vests in the concessionaire upon completion (new establishment, enlargement, or improvement) of the facility.

Source: the Article 3 of the Basic Plan for PPP. Retrieved from http://www.pimac.kdi.re.kr

BTO arrangements are normally implemented for profitable projects such as toll roads and railroads, characterized by high risk and high return. On the other hand, non-profitable projects such as schools and hospitals apply a BTL arrangement, for low risk and low return.

In addition, BTO-rs and BTO-a arrangements were introduced in 2016. These share investment and demand risk between governments and the private sector in order to promote public interest by mitigating the fiscal burden and adjusting user fees. These two types are suitable for medium risk and medium return compared with BTO and BTL.

3) Payment Mechanisms

Unlike the payment mechanisms used in other countries, such as a shadow toll or availability payments for road projects, the Republic of Korea has a unique system. Minimum Revenue Guarantee (MRG) payments are mostly adopted in developing countries to attract private investors, while on the other hand, Minimum Cost Compensation (MCC) payments are similar to availability payment mechanisms but place less focus on the availability of the facility.

a) Minimum Revenue Guarantee Payments

Among the arrangements mentioned above, the private sector or a developer assumes the demand risk for BTO projects, while the public sector takes responsibility for demand risk in BTL projects by making lease payments to the private sector. However, to attract private investors, the Republic of Korea offered MRGs for BTO PPP projects with contracts signed from January 1999 to October 2009. The government made payments to contractors if project revenue fell below certain levels, as clarified on the implementation agreement. Conversely, if revenue exceeded an upper bound, the excess was shared between the private investor and the government.

As of the end of 2008, about 1,390.3 billion KRW in MRG subsidies had been paid to private project companies. Early projects started operation but generated only 50% of expected demand on average. Many government payments were provided as MRG subsidies annually. (Kim et al., 2011)

One criticism of the MRG system was that the government took most of the risk, while providing unreasonably high returns to private participants. Higher MRG levels implied more risk transfer from private participants to the government. Another criticism was that the project company may display morally hazardous behavior, losing motivation to increase revenue since it did not bear the bulk of the risk. (Kim et al., 2011)

In an October 2009 revision of the PPP Basic Plan, the government abolished the MRG scheme.(Kim et al., 2011) However, projects with an implementation agreement dated before 2009 still received MRG payments from the government.

b) Minimum Cost Compensation Payments

According to the Basic Plan (2016), ongoing BTO projects can change their implementation conditions such as risk sharing methods and toll rate decisions given excessive fiscal burdens due to MRG payments or expected termination due to operation loss. In this situation, MRG payments could be changed to MCC.

MCC helps maintain the BTO scheme in which private investment costs are recouped through user fees paid by infrastructure/facility users while private investment costs and minimum opportunity costs in excess of user fee revenue are compensated by a relevant authority. This scheme reduces investment risk while keeping the BTO model's purpose and operation mechanism intact. MCC ensures a project company can recoup private investment costs not covered by user fee revenue in a stable manner while easing the government's payment burden by lowering the rate of return compared to MRG.(APEC, 2014)

2.2 Performance Evaluation of PPP Projects

Many authors have attempted to evaluate the success of PPP projects by such means as Key Performance Indicators (Mladenovic, Vajdic, Wundsch, and Temeljotov-Salaj, 2013; Yuan, Zeng, Skibniewski, and Li,2009), Critical Success Factors (Walter and Scholz, 2007; Zhang, 2005), and by assessing value for money aspects (Burger and Hawkesworth,2011; Grimsey and Lewis, 2005; Nisar, 2007), but no single methodology for assessment has been widely accepted as the best due to the contextual complexity of construction projects. It appears that insufficient research has been undertaken on the success or failure of PPPs to date; there is a serious need for a rigorous assessment of PPPs. (Liyanage and Villalba-Romero,2015)

In the Republic of Korea as well, strong, in-depth quantitative evaluations of PPP projects have been sparse, especially in the academic field. Earlier studies focused on certain areas such as risk management, inducement for project financing, and policy design and direction.

The Ministry of Land, Infrastructure and Transport has been conducting an annual operation assessment of PPP roads since 2011. However, this review is weighted towards satisfying users and public support rather than considering Special Purpose Company's (SPC) profitability and financial stability. Service quality for public facilities is also very important from the government's perspective, but private investors consider profitability and financial stability to be the most crucial factors influencing their decisions to invest in PPP projects. Regarding the establishment of the PPP system, it was first introduced in the Republic of Korea to promote private capital investment in SOC, solving the SOC budget deficit to enable Korea's economy to develop more rapidly. Even though high profitability and financial stability are the first prerequisites for investment in SPC, the Korean government often disregards this fact. Furthermore, the government tends to have a negative view of SPC's high profitability because it considers high profitability to be possible only when excessive profit levels are supported through minimum revenue guarantees.

A recent study by KDI completed in 2017 involved Qualitative Comparative Analysis (QCA) and DEA, using financial factors to assess the performance of PPP road projects. This attempt was path-breaking but insufficient to explain the success factors of top-ranked projects and failure factors of SPC ranked at the bottom.

2.3 DEA for Road Projects

The DEA method for measuring the relative efficiency of a set of similar DMUs was originally presented by Charnes, Cooper and Rhodes. The model determines, for each DMU, a set of virtual multipliers or factor weights such that the ratio of weighted outputs to weighted inputs for the DMU in question is maximized. This ratio becomes the DMU's relative efficiency measure (Cook, W. D., Roll, Y., and Kazakov, A. 1990).

Studies have been done with various focuses such as hospitals, schools, ports, banks, and roads to adopt the DEA method to assess performance over the past few years. By 1990, DEA was becoming fully developed, and significant advances had been made on all fronts: models, extensions, computation, and practice (Seiford, L. M. 1996).

Research by Cook et al. (1990) applied DEA to measure the efficiency of highway maintenance, accommodating multiple inputs and outputs and ranking orders patrols. Rouse and Putterill (2005) expanded on previous studies by comparing efficiency before and after local government amalgamation (Shin and Kim, 2009). Shin and Kim (2009) adopted the DEA method to evaluate the construction, operation, and profit efficiency of 4 PPP road projects and 15 public road projects. The public projects presented higher construction and operation efficiency.

Meanwhile, in Shin's 2009 study, PPP projects presented higher profit efficiency simply due to imposing higher tolls. Similar research has been done subsequently, but no in-depth analysis or suggestions have been offered because existing studies did not fully consider the differences between PPP and public projects and simply compared them from a public perspective. Public projects have the disadvantage of project delays due to limited budgets, inefficient procedures, and expected cost increases, but the PPP system has been introduced to solve this. PPP projects progress in a timely manner within budget, but investors pursue certain rates of return, which makes PPP project costs higher than for public projects. Therefore, it could be more meaningful to measure efficiency and find implications among PPP projects than to conduct a simple comparison between public and PPP projects.

Ⅲ. Methodology

3.1 Method for Measurement of Efficiency

There are several ways to measure efficiency quantitatively: ratio analysis, the productivity index method, a functional approach (regression analysis), and non-parametric frontier estimation are the most commonly used, representative options. DEA is included in non-parametric frontier estimation.

1) Ratio Analysis

Ratio analysis is an analytical method that is useful for evaluating the financial and business performance of a company because it offers a relatively easy way to measure efficiency. Ratios are applied in various ways, such as financial ratios, cost-benefit analysis, and cost-effectiveness analysis, with each step based on single or multiple ratios that can be compared. This type of ratio analysis uses financial statements to calculate financial ratios that can explain the economic situation of the company, allowing for comparison with ratios representing a company's own standard or the industry standard to evaluate profitability, liquidity, stability, and growth potential (Park, 2008).

2) Productivity Index Method

The productivity of a firm is defined as the ratio of input factors to output factors. Productivity is measured as the total productivity of the index type, productivity of each factor such as labor and capital, and total factor productivity. For total productivity, the ratio of total inputs to outputs offers an easy way to measure the overall efficiency of a firm, while factor productivity is useful for measuring productivity based on inputs. Total Factor Productivity (TFP) is useful from an economic point of view since productivity is measured in terms of added value.

This total productivity index method has an advantage in that it can easily provide information on production management to companies, but there are also several disadvantages. First, with this method productivity is calculated by converting output and input factors into amounts to determine nominal productivity. In this process, distortion of real production may occur. Second, it is not easy to identify what part of an enterprise is inefficient with the information provided. Therefore, it is difficult to substantially improve the productivity and efficiency of an enterprise using the results of the total productivity index method.

3) Functional Approach (Regression Analysis)

The functional approach measures efficiency by comparing the level of actual output to the level of expected output, assuming that the output of a company is determined by the input level. If the actual output level using a given input element is below expectations, then efficiency is considered to be low for the company.

The functional approach is essentially parametric. That is, the function formula for the output produced using an input element should be assumed. Regression analysis is one method of determining whether independent and dependent variables are correlated and how independent variables change dependent variables.

Regression models include random errors for output and input variables, which are assumed to reflect inefficiency. However, separating inefficiency from the error term is not an easy process and requires strong assumptions about the distribution of inefficiencies (Kim, 2006). Nonetheless, regression analysis can be used to estimate the efficiency of a company producing a single output by entering the number of input factors used while controlling the size and range of the industry.

However, regression analysis has the following limitations. First, since regression analysis assumes a single function formula, output should be a single item, so it is not a suitable method of analysis for a company producing a large number of outputs. Second, regression analysis is an analytical method that measures the relative efficiency of a firm by comparing average performance with the least squares method. It is difficult to obtain ideal efficiency with this approach. Third, even in the same function model, output units may be different or the result may be distorted due to price effects when converting output prices.

4) Non-parametric Frontier Approach (DEA)

The functional method discussed above is a stochastic approach to measuring efficiency by estimating the empirical cost or production frontier from observed data, which is a traditional efficiency analysis method that estimates the parameters of the production or cost function. This is the method preferred by most economists, where the form of the production function, such as the isoquant curve, is known or statistically estimable.

An advantage of the functional method is that any assumption can be statistically validated and the relationship between inputs and outputs follows the form of a function. However, when an accurate cost function for the public or service sectors cannot be easily derived, or if it is difficult to identify an objective relationship between inputs and outputs, it becomes hard to characterize production and inappropriate to discuss the efficiency of the production function.

Because of the limitations of this traditional efficiency analysis method, a non-parametric approach should be used to measure the efficiency of industries with few assumptions and constraints, and multiple inputs and outputs. The DEA model was proposed by Charnes, Cooper and Rhodes (1978) based on the concept of efficiency defined by Farrell (1957). The DEA model is a linear planning methodology designed to measure the relative efficiency of DMUs that perform similar types of management activities, using data on multiple inputs and outputs. It is a frontier approach that evaluates efficiency by specifying a best practice unit and then comparing this with other DMUs.

3.2 DEA Model

1) Properties of DEA

Since the DEA analysis method first appeared, it has been used for efficiency analyses in various fields. The DEA model is used to find benchmarking DMUs[1] to improve the efficiency of inefficient DMUs.

The original idea behind DEA was to provide a methodology whereby, within a set of comparable DMUs, those exhibiting best practice could be identified and would form an efficient frontier. Furthermore, this methodology enables one to measure the level of efficiency of non-frontier units and to identify benchmarks against which such inefficient units can be compared (Wade D. Cook et al., 2009).

DEA can be used to measure relative efficiency by estimating a producible set and a boundary based on input and output data for each DMU when there are multiple input and output factors. DEA has the disadvantage that it cannot be used to estimate the direct effect of DMUs, but it is accepted as an attractive analysis framework given that results are relatively easy to interpret and are convincing (Kim, 2011). The advantages of DEA will be examined in detail below.

First, DEA does not presume the weights for input and output data in advance.

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[1] A Decision Making Unit (DMU) is considered to be technically efficient if, from the basket of inputs it holds, it produces the maximum outputs possible or if, to produce a given quantity of outputs, it uses the smallest quantity of inputs possible (Atkinson and Cornwell, 1994).

The stochastic frontier approach, or non-frontier approach, measures performance by taking a weighted average score of indicators after assigning weights in advance according to the relative importance of the indicators. However, in this process, weighting by relative importance can be influenced by evaluator subjectivity. On the other hand, the weight of input and output elements for DEA is obtained from benchmarking DMUs, thus ensuring objectivity in performance measurement and evaluation (Kim and Choi, 2005).

Secondly, if a specific production function is unknown or difficult to describe due to multiple input and output factors, it is possible to compare the efficiency of a particular DMU with other similar DMUs, indicating the relative degree of efficiency (Kim and Choi, 2005). Therefore, DEA is useful for evaluating nonprofits or public agencies that have multiple inputs and outputs and whose production function is unknown.

Third, DEA can allow for the development of a management strategy to improve efficiency if the DEA model includes controllable inputs (Jung and Kang, 2006). Each organization can work toward improving its efficiency by seeking management strategies for input and output elements using efficiency frontier information obtained through DEA.

Meanwhile, according to Ko (2017), the disadvantages of DEA are as follows. If all DMUs have the same efficiency rating due to inefficiency inherent in the whole organization being analyzed, DEA will be useless (Ko, 2017). Next, depending on how inputs and outputs are selected, efficiency measurement results may vary (Ko, 2017). Third, DEA offers a good way to measure relative efficiency, but absolute efficiency cannot be measured. Finally, as a non-parametric method, the statistical test involved is difficult to complete (Ko, 2017).

Ⅳ. Analysis

4.1 DEA Models (BCC, Input Oriented)

The most widely used DEA models are the CCR and BCC models. The CCR model was named after Charnes, Cooper, and Rhodes who introduced the technique, and the BCC model was named after Banker, Charnes and Cooper. The difference between these two models lies in the assumptions used to define the producible set or efficiency boundary. When determining a producible set, the CCR model assumes free disposability, convexity, and constant returns to scale; the BCC model assumes free disposability, convexity, and variable returns to scale. For this analysis, a BCC model was used. Since economies of scale can exist, it was necessary to mitigate the assumption of constant returns to scale.

When addressing a realistic problem, whether to select an input-oriented or output-oriented approach must be considered. An input-oriented model assumes that input factors can be controlled. Therefore, if target output is given, an input-oriented model is appropriate since input can be managed to achieve efficiency. An output-oriented model, on the other hand, is appropriate when efficiency is to be achieved by adjusting the output from a given input.

Input and output directions for the CCR and BCC models can be set, and multiplier and envelopment models can be used. Using the multiplier model, efficiency priorities among DMUs can be determined. It is also easy to conclude how input and output elements should be weighted to achieve optimal efficiency. The envelopment model provides the same results as the multiplier model but gives more information for interpreting the results. It is widely used, especially in judging strong and weak levels of efficiency and in reference DMU analysis. In DEA, the envelopment model is more general than the multiplier model. The reason DEA is referred to as a data envelopment model is that it calculates efficiency from the perspective of an envelopment model.

In the case of efficiency for a road project, since output is dependent on input and SPC has discretion over financial resources, the input-oriented model is reasonable. Therefore, in this study, an input-oriented BCC model has been used for analysis.

Input-oriented envelopment analysis can be said to offer "a model that finds a ratio θ where all input factors are reduced to minimize the input level, while achieving at least the same level of output."

When applying the linear programming method, an efficiency boundary using linear combinations for the input factor ($\sum_{i=1}^{q} x_{ii} \lambda$) and the output element ($\sum_{i=1}^{q} y_{ir} \lambda$) are created. Next, constrains are imposed so DMU outputs are smaller than or equal to the outputs of the efficiency boundary, while DMU inputs are greater than or equal to the inputs of the efficiency boundary. Input-oriented models are based on the logic that the value that minimizes the distance from the efficiency boundary should become the efficiency score.

The relevant linear programming objective function and constraints for input-oriented BCC envelopment analysis are below.

Figure 1

Index for Input-Oriented BCC Envelopment Analysis Model

<Index>

j: jth DMU $(j = 1, \cdots, n)$

i: i th input factor ($i = 1, \cdots, m$)

r: r th output factor ($r = 1, \cdots, s$)

k: Certain kth DMU for calculating efficiency

n: Total number of DMUs

m : Total number of input factors

s: Total number of output factors

<Data>

y_{rj} : rth output factor of jth DMU

x_{ij} : ith input factor of jth DMU

<Variable>

v_i: Objective function of ith input factor's Contribution coefficient

u_r : Objective function of rth output factor's Contribution coefficient

s_i^- : Slack variable of rth input factor

s_r^+ : Slack variable of rth output factor

λ_j: Weight of jth DMU

Figure 2

Input-Oriented BCC Envelopment Analysis

$$Min\ \theta_k - \epsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

s.t.

$$\theta_k x_{ik} - \sum_{j=1}^{n} x_{ji}\lambda_j - s_i^- = 0 \quad , \ i = 1,2,\ldots,m$$

$$y_{rk} - \sum_{j=1}^{n} y_{jr}\lambda_j + s_r^+ = 0 \quad , \ r = 1,2,\ldots,s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, s_i^- \geq 0, s_r^+ \geq 0$$

4.2 Input and Output Factors

In this research, the main challenge for selecting input and output factors was variability depending on perspectives for measuring efficiency. For example, government subsidies related to MRG regulations are a cost for the government but represent earnings for the SPC. On the other hand, interest expenses area cost for the SPC but a major source of income for investors. Also, because PPP projects are also PF projects, cash flow varies depending on the structure of principal repayment, and the construction period and operating period should be viewed as a whole. Along these lines, a factor can be considered either an input or output, or simply excluded, depending on the perspective taken.

Therefore, in this study, efficiency was measured from the perspective of SPC, which seeks profit. This implies that input factors are cost-based and output factors are profit-based. Considering the life cycle of PPP projects, the cost or profit from financing, construction, and operation need to be included. Operating cost is generally used as an input factor for operating and maintenance efficiency analysis, but Amortization of Management and Operation Rights (AMOR, a period cost of construction cost) and interest expense (financing cost) are also included for this analysis. On the other hand, sales and values related to SPC's profit such as Cash Flow from Operating Activities (CFOA, a major consideration for lenders) and traffic volume have been chosen as output factors.

However, MRG funds were excluded because they result from policy rather than efficiency of the project itself. Finally, three input and three output factors were chosen for analysis.

- Input Factors: Operating cost, Amortization of Management and Operation Rights (AMOR), interest expense
- Output Factors: Cash Flow from Operating Activities (CFOA), traffic volume, sales

1) Input Factors

The costs incurred by SPC can be divided into three categories. Explained simply, operational costs are incurred when operating. Since operation expenses in the published audit report include the Cost of Goods Sold (COGS) and Selling, General and Administrative (SGA) expenses, the summed value of these two costs was chosen as the first input factor. However, AMOR as a non-cash expense accounts for the largest portion of operating expenses. Amortization expense is the cost of amortizing total private investment costs for construction using mostly a straight-line method every year during the operation period. However, it is not incurred from operation itself, so it has been excluded from operating cost.

However, total private investment costs are also expenses for construction of facilities, so AMOR, which is a related annualized cost, should be considered a cost associated with generating profit. If amortization methods had differed for each company, the efficiency value may have been greatly affected, but almost all SPCs amortize intangible assets using a straight-line method over the operating period. Therefore, this value was included as an input factor serving as a proxy for construction cost.

Meanwhile, as a kind of PF project, PPP projects have a very high debt ratio (debt accounts for 80-90% of total investment), which causes high interest costs. Considering financing aspects such as payable conditions or the possibility of insolvency is very important when measuring the efficiency of SPCs.

2) Output Factors

Output factors included CFOA, traffic volume, and sales. Revenue was included as the most basic output. On the other hand, revenue from MRG was excluded from sales. Including MRG could distort the perceived efficiency of a project since it represents a grant for projects established before 2007, irrespective of the efficiency of the project itself.

In addition, CFOA was chosen to assess whether SPCs could repay principle and interest payments with net operating cash flow. Because it is difficult to obtain Earnings Before Interest, Tax, Depreciation and Amortization (EBITDA) from published data, CFOA from the cash flow statement within the published audit report was used. CFOA is a cash balance that excludes cash operating expenses from revenue, excluding MRG, and can be useful to indicate whether principal and interest payments can be redeemed with cash. Finally, the traffic volume representing how many users access a facility per day was necessary for determining the performance of projects as a complement of sales.

4.3 Data and Analysis Method

In a DEA model, the total number of input and output variables and the total number of DMUs to be evaluated are related. In other words, if the number of selected variables is larger than the number of DMUs, then the discriminative power of the model to distinguish between efficient and inefficient units is greatly reduced. In empirical general principles, the total number of DMUs must be greater than the number of input and output factors. In order to compare highway construction efficiency, maintenance efficiency and profitability under theoretical and empirical assumptions, a total of 35 projects for which public data was available among 37 PPP roads in operation in 2016 were selected. Roads composed of only tunnels and bridges were divided into different groups because of differences with general roads, such as road length and construction cost. The samples included 13 tunnels and bridges, and 22 main roads.

Table 2

Number of PPP Roads in Operation as of 2016

Operation starting year	Project No.
2000	1
2001	2
2002	4
2003	-
2004	4
2005	1
2006	3
2007	1
2008	3
2009	4
2010	2
2011	2
2012	-
2013	4
2014	2
2015	1
2016	3

Total	37

Source: PIMAC Infra info DB

Among the above projects, 27 have MRG provisions, with 10 of these provisions since abolished, 6 MRG provisions remaining but not paid, and 11 paid.

Table 3

PPP Roads in Operation as of 2016

(unit: million KRW)

Type	Projects (DMU name)	Total private investment cost	Operation started	Size (km)	Operating years
Bridge/Tunnel	Bukhang I'Bridge Co., Ltd. (Busan)	500,357	2014	3.30	30
	Eulsukdo Bridge Co., Ltd. (Busan)	443,071	2010	5.20	30
	GK Fixed Link Corp. (Busan-Geoje)	1,952,327	2011	8.20	40
	Ilsan Grand Bridge Corporation	210,490	2008	1.80	30
	Incheon Bridge Co., Ltd.	1,539,177	2009	12.30	30
	Machang Bridge Corp.	368,375	2008	1.70	30
	Manwolsan Tunnel Co., Ltd. (Incheon)	124,004	2005	2.90	30
	Mishiryung Area Development Co., Ltd.	113,530	2006	15.70	30
	Mun Hack Development Co., Ltd. (Incheon)	66,645	2002	1.50	20
	The Ulsan Harbour Bridge Co., Ltd.	441,877	2015	8.40	30
	Wonjecksan Tunnel Inc.	84,303	2004	2.30	30
	Woomyunsan Development Co., Ltd. (Tunnel)	163,183	2004	3.00	30
	Yongma Tunnel Co., Ltd.	176,606	2014	3.60	30
Main Road	Busan Ulsan Expressway Co., Ltd.	1,260,623	2008	47.20	30
	CheonanNonsan Expressway Co., Ltd.	1,538,378	2002	81.00	30
	Daegu East Circulation Road Co., Ltd.	161,205	2002	7.30	24
	Daegu South Circulation Road Corporation	387,928	2013	10.40	26
	Daejeon Riverside Expressway Co., Ltd.	120,135	2004	4.90	30
	Gwangju Belt-Highway Inc. (Section 4)	191,547	2007	4.50	30
	Gyeonggi Highway Co., Ltd. (West Suwon- Pyeongtaek)	1,035,573	2009	38.50	30
	GYEONGSU Highway Co., Ltd. (YongIn- Seoul)	993,855	2009	22.90	30
	Kangnam Beltway Co., Ltd.	1,203,369	2016	12.40	30

	(Seoul)				
	Kwangju Ring Road Co., Ltd. (Section 3)	144,323	2004	3.50	30
	Kwangju Ring Road Co., Ltd. (Section 1)	175,084	2001	5.70	28
	Kyunggi South Road Co., Ltd.	353,885	2013	13.10	29
	Metropolitan Western Expressway Co., Ltd.	1,287,165	2016	27.40	30
	Namyangju Urban Expressway Co., Ltd.	227,938	2011	11.20	30
	New Airport Highway Co., Ltd. (Incheon)	1,425,110	2001	40.20	30
	New Daegu Busan Expressway Co., Ltd.	2,332,278	2006	82.10	30
	Seoul Beltway Corp.	1,339,533	2006	36.30	30
	Seoul-Chuncheon Highway Co., Ltd.	1,742,343	2009	61.40	30
	The 2nd Seohaean Expressway Co., Ltd.	844,121	2013	42.60	30
	The 2nd Youngdong Highway Co., Ltd. (Seoul-Wonju)	1,137,893	2016	57.00	30
	The Gyeongnam Highway Co., Ltd. (Changwon- Busan)	250,931	2013	22.50	30
	The Third Gyeongin Highway Co., Ltd.	695,432	2010	14.30	30
	Mean	715,217	2009	20.47	29.63

Source: PIMAC Infra info DB, www.dart.or.kr

This analysis has been conducted using the SAS macros for BCC analysis developed by Ko (2017).

4.4 Descriptive Statistics

Among the 37 projects, published financial information for two could not be found, so 35 projects were included in actual analysis.

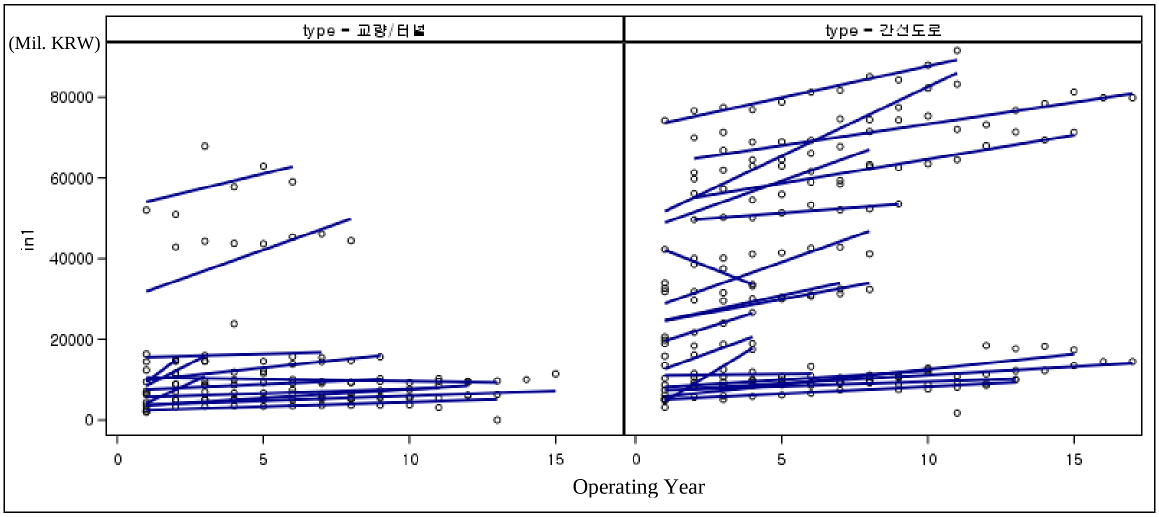
1) Input Factors

a) Operating Cost

Overall, operating costs have increased as operation continued. Main roads have higher operating costs and larger variations by SPC (DMUs) than bridges/tunnels.

Figure 3

Annual Operating Cost Trends by Project

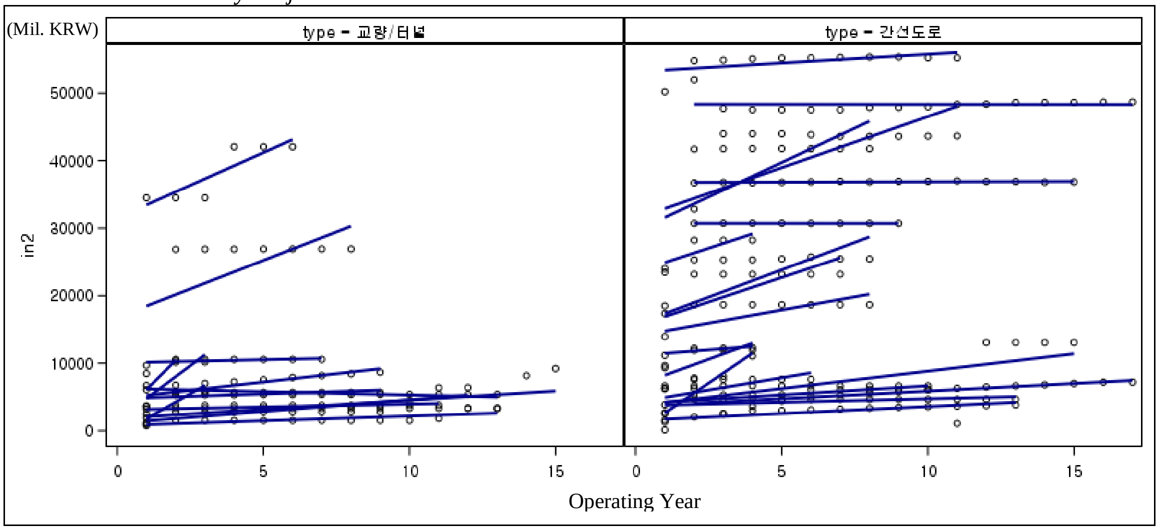


b) Amortization of Management and Operation Rights

AMOR maintained a fairly constant level due to the fact that overall investment expenses were amortized using a straight-line method over the operating period. However, there were some cases where amortization of SPC suddenly increased due to an increase in management and operation rights. For example, GK Fixed Link Corp. (Busan-Geoje), in connection with one of the bridges/tunnels, had new investors who were willing to apply more input for less output due to a change in the macroeconomic environment, such as low interest rates. On the other hand, in the first year, amortization expense may be lower than during other operating years due to amortization on a monthly basis.

Figure 4

Annual AMOR Trends by Project

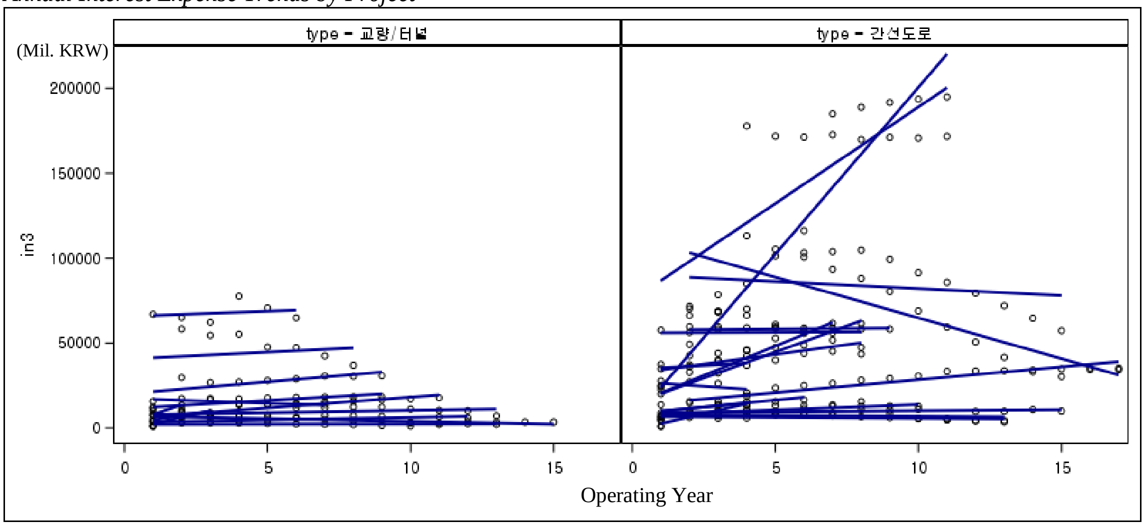


c) Interest Expense

SPC of bridges/tunnels pay a certain amount of interest annually, while main roads were divided into projects with constant, increasing, or decreasing interest costs. If the repayment date of the principal of the debt has not yet arrived, interest should be paid steadily. Once the principal is repaid, interest costs will decrease. However, if interest costs are increasing, this can be a negative sign because the financial situation of SPC will become worse with additional borrowing.

Figure 5

Annual Interest Expense Trends by Project



Of the 35 projects, four projects had three input factors included in the top five. Three projects (New Daegu Busan Expressway Co., Ltd.; New Airport Highway Co., Ltd. (Incheon); and Seoul Beltway Corp.) composed the main road group, and one (GK Fixed Link Corp. (Busan-Geoje)) represented the bridge/tunnel group.

In the case of the New Daegu Busan Expressway Co., Ltd., road length was 82.1 km, the longest among the 37 roads. The other two main roads were also relatively long; the length of New Airport Highway Co., Ltd. (Incheon) was 40.2 km, while Seoul Beltway Corp. was 36.3 km. The average length of the 37 roads was 19.1 km, with a standard deviation of 22.2. GK Fixed Link Corp. (Busan-Geoje) was only 8.2 km but was designed using a complex and expensive construction method, the “submerged tunnel method.” For the four road projects considered, the size of the project (including total investment cost, road length, and construction method) had an effect on input factors.

On the other hand, there were four projects with all three input factors ranked in the lower five (Wonjecksan Tunnel Inc.; Mun Hack Development Co., Ltd. (Incheon);

Manwolsan Tunnel Co., Ltd. (Incheon); and Kwangju Ring Road Co., Ltd. (Section 3)). All four roads were fairly short: less than 4 km.

Table 4

Input Factor Descriptive Statistics

	N (operating years)	Operating cost (Mil. KRW)	AMOR (Mil. KRW)	Interest expense (Mil. KRW)
Mean	8.4	25,806	16,292	31,726
Standard deviation	4.6	22,491	14,638	33,057
Min	1	3,775	1,763	2,359
Max	16	81,468	54,699	143,514
Sample number	35	35	35	35

Table 5

Input Factor Descriptive Statistics by Project

Type	DMU_name	N	Operating cost (Mil. KRW)			AMOR (Mil. KRW)			Interest expense (Mil. KRW)		
			Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Bridge/Tunnel	Bukhang I'Bridge Co., Ltd. (Busan)	3	12,174	7,165	14,842	8,013	3,700	10,183	7,286	3,657	9,323
	Eulsukdo Bridge Co., Ltd. (Busan)	7	16,167	14,457	23,839	10,427	9,673	10,552	15,108	13,639	17,419
	GK Fixed Link Corp. (Busan-Geoje)	6	58,439	50,987	67,880	38,280	34,519	42,041	67,814	62,115	77,448
	Ilsan Grand Bridge Corporation	9	8,832	6,259	10,289	5,459	3,586	5,694	16,181	9,849	18,343
	Incheon Bridge Co., Ltd.	8	40,871	16,350	46,121	24,382	6,698	26,939	44,181	11,437	58,217
	Machang Bridge Corp.	9	12,953	6,645	15,950	7,215	3,244	8,654	27,104	12,083	30,705
	Manwolsan Tunnel Co., Ltd. (Incheon)	12	6,081	2,681	10,290	3,373	1,186	6,390	5,169	1,464	7,406
	Mishiryung Area Development Co., Ltd.	11	6,809	4,357	8,656	3,614	1,903	3,788	13,011	3,969	17,748
	Mun Hack Development Co., Ltd. (Incheon)	15	5,499	1	11,446	3,993	2,499	9,201	4,544	1,982	6,946
	The Ulsan Harbour Bridge Co., Ltd.	2	12,142	9,451	14,833	8,260	6,087	10,434	10,688	7,822	13,553
	Wonjecksan Tunnel Inc.	13	3,775	1,928	6,338	1,763	760	3,331	2,359	1,050	3,742
	Woomyunsan Development Co., Ltd. (Tunnel)	13	9,914	8,875	12,369	5,601	5,334	8,479	9,457	6,727	12,331
	Yongma Tunnel Co., Ltd.	3	7,488	2,112	11,620	4,254	981	5,894	6,214	655	9,867

Main Road	Busan Ulsan Expressway Co., Ltd.	8	51,573	49,695	53,573	30,711	30,705	30,718	58,256	56,278	59,263
	CheonanNonsan Expressway Co., Ltd.	14	62,854	54,563	71,415	36,852	36,700	36,999	83,324	57,217	104,668
	Daegu East Circulation Road Co., Ltd.	15	11,056	1,700	18,452	7,794	1,088	13,059	9,790	4,284	13,573
	Daegu South Circulation Road Corporation	4	16,630	10,323	18,981	10,593	6,637	11,919	12,187	7,388	14,664
	Daejeon Riverside Expressway Co., Ltd.	13	8,804	4,868	11,152	4,431	1,542	4,672	7,204	4,326	15,559
	Gwangju Belt-Highway Inc. (Section 4)	10	10,177	6,114	13,270	5,449	2,655	6,143	10,833	5,111	12,834
	Gyeonggi Highway Co., Ltd. (West Suwon- Pyeongtaek)	8	37,847	13,521	42,825	23,033	6,301	25,752	41,580	6,538	61,599
	GYEONGSU Highway Co., Ltd. (YongIn- Seoul)	8	29,268	18,940	32,480	17,499	9,333	18,665	42,134	20,075	48,631
	Kangnam Beltway Co., Ltd. (Seoul)	1	20,561	20,561	20,561	13,955	13,955	13,955	22,548	22,548	22,548
	Kwangju Ring Road Co., Ltd. (Section 3)	13	7,210	5,035	9,981	2,968	129	3,828	6,006	655	7,782
	Kwangju Ring Road Co., Ltd. (Section 1)	16	10,931	5,123	14,495	5,760	2,481	7,204	27,603	9,211	34,745
	Kyunggi South Road Co., Ltd.	4	23,030	19,793	26,663	11,970	11,164	12,297	24,515	20,638	27,003
	Metropolitan Western Expressway Co., Ltd.	1	32,634	32,634	32,634	24,044	24,044	24,044	37,386	37,386	37,386
	Namyangju Urban Expressway Co., Ltd.	6	11,296	7,398	16,129	6,760	2,533	7,621	13,913	4,882	16,465
	New Airport Highway Co., Ltd. (Incheon)	16	72,836	64,456	81,307	48,338	47,527	51,962	67,159	30,154	113,120
	New Daegu Busan Expressway Co., Ltd.	11	81,468	74,245	91,598	54,699	50,222	55,341	143,514	57,534	177,786
	Seoul Beltway Corp.	11	68,869	33,930	83,262	40,471	18,491	43,992	121,948	24,794	194,964
	Seoul-Chuncheon Highway Co., Ltd.	8	57,963	31,844	63,266	38,705	17,364	41,770	56,221	27,669	70,214
	The 2nd Seohaean Expressway Co., Ltd.	4	37,868	33,169	42,270	27,036	23,480	28,223	36,753	34,846	39,339
	The 2nd Youngdong Highway Co., Ltd. (Seoul-Wonju)	1	8,676	8,676	8,676	6,203	6,203	6,203	8,820	8,820	8,820
	The Gyeongnam Highway Co., Ltd. (Changwon- Busan)	4	11,175	3,121	17,444	7,059	1,300	11,063	8,372	1,110	13,977
	The Third Gyeongin Highway Co., Ltd.	7	29,325	15,820	33,621	21,250	9,659	23,183	41,247	13,546	55,910

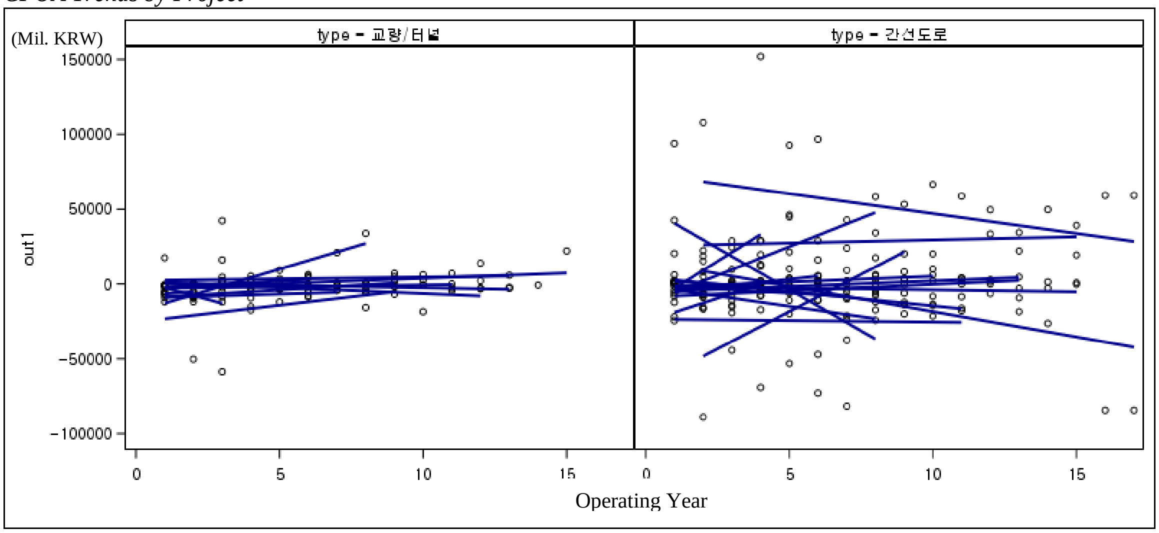
2) Output Factors

a) Cash Flow from Operating Activities (CFOA)

Projects in the bridge/tunnel group mostly revealed a constant cash flow, nearly or less than zero. The main roads group was more complex, with most projects showing constant cash flow but larger standard deviation than the bridge/tunnel group. Some had an increasing cash flow, some decreasing.

Figure 6

CFOA Trends by Project

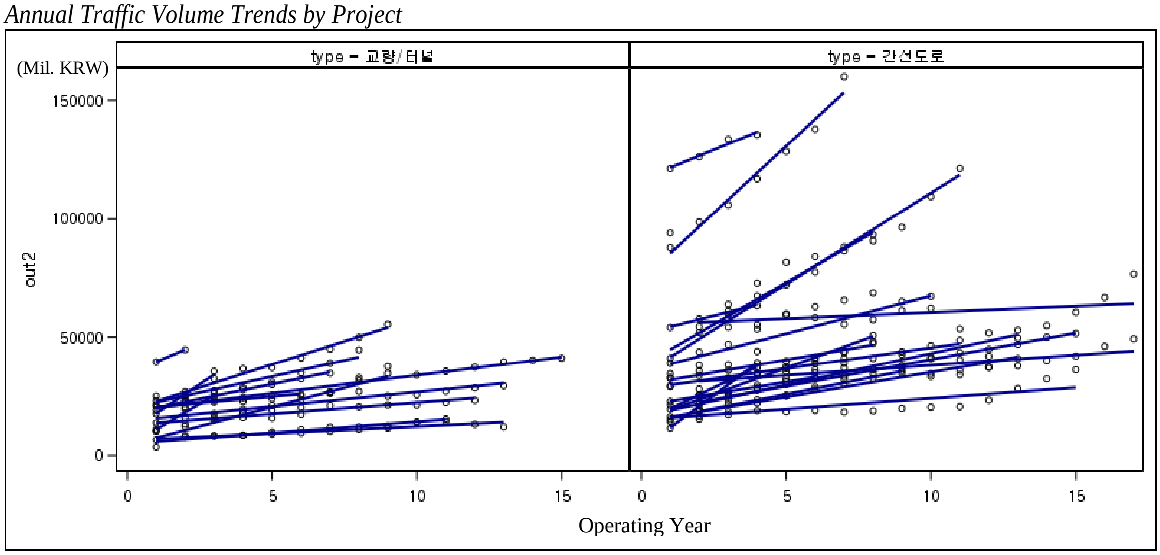


b) Traffic Volume

Traffic volume showed an upward trend overall. The main roads group had more traffic volume than the bridge/tunnel group.

Figure 7

Annual Traffic Volume Trends by Project

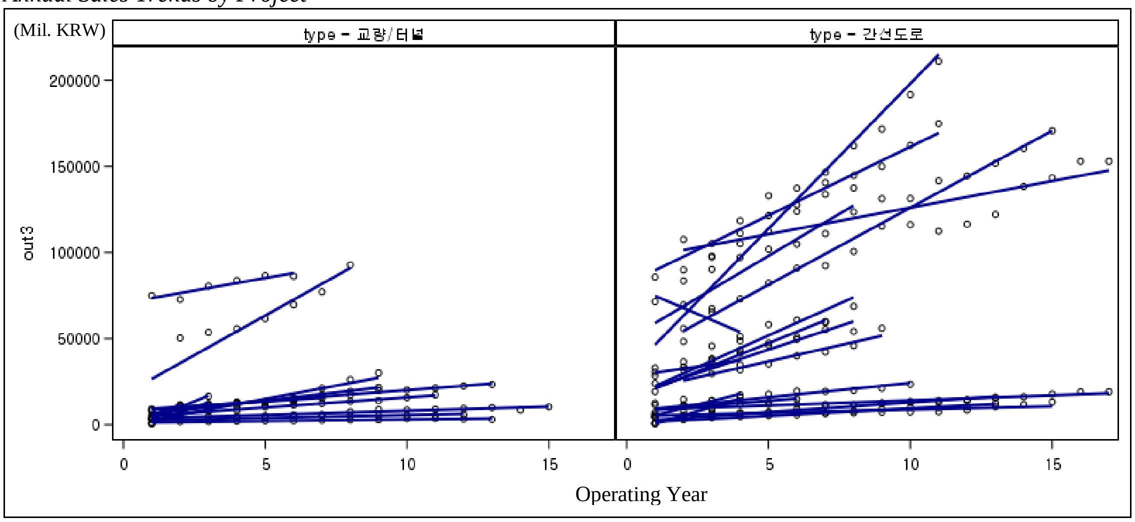


c) Sales

The sales factor also showed an upward trend. There were projects in both groups that demonstrated constant or increasing patterns.

Figure 8

Annual Sales Trends by Project



The average of the three output factors for the main roads group was higher than for the bridge/tunnel group. The size of projects gave rise to this result: main roads were generally longer, causing higher tolls and greater traffic volume than for bridges/tunnels.

Of the 35 projects, only one, New Airport Highway Co., Ltd. (Incheon), had three input factors included in the top five. This project also included the inputs in the top five.

On the other hand, no project had all three input factors in the lower five.

Table 6

Output Factor Descriptive Statistics

	N (operating years)	Sales (Mil. KRW)	Traffic volume (per day)	CFOA (Mil. KRW)
Mean	8.4	35,845	41,230	1,476
Standard deviation	4.6	39,117	27,576	15,244
Min	1	2,521	10,505	-24,582
Max	16	130,660	129,160	48,427
Sample number	35	35	35	35

Table 7

Output Factor Descriptive Statistics by Project

Type	DMU_name	N	Sales (Mil. KRW)			Traffic volume (per day)			CFOA (Mil. KRW)		
			Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Bridge/Tunnel	Bukhang I'Bridge Co., Ltd. (Busan)	3	10,237	3,252	16,544	25,937	19,153	35,536	(7,697)	(11,973)	(1,515)
	Eulsukdo Bridge Co., Ltd. (Busan)	7	12,467	7,840	15,309	27,673	17,622	34,773	(7,270)	(17,422)	(3,480)
	GK Fixed Link Corp. (Busan-Geoje)	6	80,831	72,784	86,648	23,282	20,451	25,443	538	(50,297)	42,320
	Ilsan Grand Bridge Corporation	9	13,996	4,517	21,747	38,461	21,461	55,429	(3,949)	(9,026)	7,174
	Incheon Bridge Co., Ltd.	8	58,790	9,166	92,792	32,013	25,086	44,561	7,145	(11,925)	33,900
	Machang Bridge Corp.	9	15,002	3,695	30,109	20,462	10,379	37,657	(14,173)	(58,664)	1,275
	Manwolsan Tunnel Co., Ltd. (Incheon)	12	4,465	1,041	5,847	19,013	11,163	23,329	(3,531)	(18,487)	4,646
	Mishiryung Area Development Co., Ltd.	11	11,206	3,777	17,381	10,505	3,500	15,429	(1,632)	(4,550)	153
	Mun Hack Development Co., Ltd. (Incheon)	15	7,163	3,292	10,370	30,857	22,530	41,082	2,416	(6,967)	22,188
	The Ulsan Harbour Bridge Co., Ltd.	2	8,637	5,752	11,521	42,096	39,513	44,679	(5,832)	(6,446)	(5,218)
	Wonjecksan Tunnel Inc.	13	2,521	704	3,600	10,527	6,664	14,355	(1,487)	(6,872)	2,813
	Woomyunsan Development Co., Ltd. (Tunnel)	13	16,328	8,690	23,430	23,144	13,886	29,500	3,909	(2,204)	16,213
	Yongma Tunnel Co., Ltd.	3	7,306	554	11,927	18,217	10,342	24,667	(1,107)	(4,862)	1,885
Highway	Busan Ulsan Expressway Co., Ltd.	8	38,688	28,293	56,107	27,060	18,599	37,016	(13,415)	(88,858)	8,215
	CheonanNonsan Expressway Co., Ltd.	14	112,591	55,817	170,727	37,126	21,859	51,599	28,854	(26,322)	66,589
	Daegu East Circulation Road Co., Ltd.	15	8,063	6,025	13,268	22,320	18,403	36,269	(3,350)	(10,612)	9,785

	Daegu South Circulation Road Corporation	4	11,700	4,589	17,257	28,630	19,630	37,008	(9,535)	(21,933)	(2,475)
	Daejeon Riverside Expressway Co., Ltd.	13	6,947	811	12,399	35,088	11,599	49,634	(2,809)	(12,181)	20,125
	Gwangju Belt-Highway Inc. (Section 4)	10	16,798	5,001	23,482	53,017	32,869	67,198	1,744	(2,382)	6,160
	Gyeonggi Highway Co., Ltd. (West Suwon- Pyeongtaek)	8	48,203	4,470	68,785	34,749	14,269	50,697	(13,490)	(72,815)	13,008
	GYEONGSU Highway Co., Ltd. (YongIn- Seoul)	8	40,907	11,521	55,329	69,476	39,005	93,327	1,877	(81,583)	93,811
	Kangnam Beltway Co., Ltd. (Seoul)	1	23,992	23,992	23,992	94,102	94,102	94,102	42,535	42,535	42,535
	Kwangju Ring Road Co., Ltd. (Section 3)	13	9,595	424	15,949	28,907	15,384	40,993	(143)	(8,379)	4,664
	Kwangju Ring Road Co., Ltd. (Section 1)	16	13,849	9,212	19,132	37,720	28,057	49,320	(16,711)	(84,282)	5,073
	Kyunggi South Road Co., Ltd.	4	33,779	28,516	38,312	129,160	121,269	135,550	(133)	(3,139)	1,603
	Metropolitan Western Expressway Co., Ltd.	1	30,619	30,619	30,619	41,059	41,059	41,059	2,482	2,482	2,482
	Namyangju Urban Expressway Co., Ltd.	6	11,911	5,068	15,020	28,016	22,823	33,254	(8)	(4,887)	5,269
	New Airport Highway Co., Ltd. (Incheon)	16	124,518	89,906	152,906	60,157	51,815	76,681	48,427	(11,034)	152,003
	New Daegu Busan Expressway Co., Ltd.	11	129,498	85,809	174,841	38,513	29,353	48,709	(24,582)	(69,069)	8,190
	Seoul Beltway Corp.	11	130,660	19,328	211,025	80,074	34,575	121,300	(6,906)	(44,252)	46,323
	Seoul-Chuncheon Highway Co., Ltd.	8	93,160	32,992	123,552	39,317	29,118	47,394	21,119	(19,184)	58,379
	The 2nd Seohaean Expressway Co., Ltd.	4	64,324	48,819	71,469	58,982	54,107	63,268	15,149	(8,052)	28,780
	The 2nd Youngdong Highway Co., Ltd. (Seoul-Wonju)	1	7,147	7,147	7,147	32,632	32,632	32,632	20,388	20,388	20,388
	The Gyeongnam Highway Co., Ltd. (Changwon- Busan)	4	7,845	953	16,001	25,374	15,188	43,934	(2,232)	(6,919)	1,756
	The Third Gyeongin Highway Co., Ltd.	7	40,816	12,642	59,587	119,402	87,854	160,006	(4,944)	(10,854)	198

Ⅴ. Results and Discussion

4.1 Analysis Results

When selecting sample projects among the 35considered, a 2-year ramp-up period was excluded from analysis. Therefore, as of the end of 2016, four projects had operated for less than three years and were excluded (Kangnam Beltway Co., Ltd. (Seoul); Metropolitan Western Expressway Co., Ltd.; The 2nd Youngdong Highway Co., Ltd. (Seoul-Wonju); and The Ulsan Harbour Bridge Co., Ltd.).

1)Main Roads

Kyunggi South Road Co., Ltd., was found to be the most efficient among the 19 main road projects included, with an efficiency score of 1. This road project was only in its fourth year of operation but showed very high traffic volume. On the other hand, other input and output factors were assessed at a middle level. A low level of sales was observed, despite the traffic volume results, given low toll fees due to the refinancing of gain sharing.

From a user's perspective, the low toll fee makes the facility accessible, and from an investor’s perspective, the project has been able to create a stable income—enough to repay principal and interest expenses while earning above expectations. In addition, from the government’s perspective, subsidies are not needed and lowering the toll was possible by refinancing gain sharing. Therefore, this project can be considered successful for all stakeholders.

The second highest score was granted to Gwangju Belt-Highway Inc. (Section 4) (0.90); the third, New Airport Highway Co., Ltd. (Incheon) (0.84); and fourth, Seoul Beltway Corp. (0.84). These three projects showed high output. However, the input level of Gwangju Belt-Highway Inc. was low, while the input levels of New Airport Highway Co., Ltd. (Incheon) and Seoul Beltway Corp were high.

Conversely, the projects with the lowest efficiency scores were Busan Ulsan Expressway Co., Ltd. (0.30); Daegu East Circulation Road Co., Ltd. (0.41); and Daegu South Circulation Road Corporation (0.42). These three were all outside the metropolitan area. Among these, Busan Ulsan Expressway Co., Ltd., required high input but had low traffic volume and cash flow.

Table 8

Annual Efficiency Score Results by Project (Main Roads)

DMU_name/year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Mean	CA GR	Rank
Busan Ulsan Expressway Co., Ltd.	0.22	0.24	0.26	0.29	0.32	0.35	0.43									0.30	12%	19
CheonanNonsan Expressway Co., Ltd.	0.52	0.59	0.69	0.65	0.68	0.71	0.85	0.97	1.00	0.97	0.90	0.96	1.00			0.81	6%	6
Daegu East Circulation Road Co., Ltd.	0.60	0.36	0.30	0.30	0.29	0.34	0.35	0.31	1.00	0.31	0.35	0.36	0.43			0.41	-2%	18
Daegu South Circulation Road Corporation	0.37	0.46														0.42	12%	17
Daejeon Riverside Expressway Co., Ltd.	0.53	0.61	0.57	0.61	0.72	0.76	0.80	1.00	0.88	0.98	1.00					0.77	6%	8
Gwangju Belt-Highway Inc. (Section 4)	0.77	0.88	1.00	0.85	0.87	0.89	0.94	1.00								0.90	3%	2
Gyeonggi Highway Co., Ltd. (West Suwon-Pyeongtaek)	0.45	0.53	0.59	0.58	0.56	0.68										0.57	7%	14
GYEONGSU Highway Co., Ltd. (YongIn- Seoul)	0.56	0.61	0.68	0.72	0.78	0.80										0.69	6%	11
Kwangju Ring Road Co., Ltd. (Section 3)	0.44	0.50	0.57	0.65	0.76	0.83	0.85	0.85	0.86	0.96	1.00					0.75	8%	9
Kwangju Ring Road Co., Ltd. (Section 1)	1.00	0.71	0.58	0.55	0.52	0.50	0.47	0.47	0.50	0.50	0.50	0.53	0.57	0.61	0.63	0.58	-3%	13
Kyunggi South Road Co., Ltd.	1.00	1.00														1.00	-	1
Namyangju Urban Expressway Co., Ltd.	0.37	0.39	0.49	0.57												0.45	11%	15
New Airport Highway Co., Ltd. (Incheon)	0.61	1.00	0.91	0.97	0.86	0.82	0.73	0.65	0.66	0.74	0.78	0.95	1.00	1.00	1.00	0.84	4%	3
New Daegu Busan Expressway Co., Ltd.	0.56	0.56	0.60	0.62	0.65	0.67	0.71	0.74	0.76							0.65	4%	12
Seoul Beltway Corp.	0.58	0.75	0.95	0.81	0.77	0.85	0.91	0.92	1.00							0.84	6%	4
Seoul-Chuncheon Highway Co., Ltd.	0.59	0.64	0.69	0.74	0.86	0.97										0.75	9%	10
The 2nd Seohaean Expressway Co., Ltd.	0.84	0.75														0.80	-5%	7
The Gyeongnam Highway Co., Ltd. (Changwon-Busan)	0.39	0.48														0.43	12%	16
The Third Gyeongin Highway Co., Ltd.	0.68	0.69	0.81	0.87	1.00											0.81	8%	5
Mean	0.58	0.62	0.65	0.65	0.69	0.71	0.70	0.77	0.83	0.74	0.75	0.70	0.75	0.80	0.81		5%	

2) Bridges/Tunnels

In total, 12 projects in the bridges/tunnels group were analyzed. Unlike main roads, the longer these projects had been operating, the more likely their efficiency score was to increase. The most efficient project was Woomyunsan Development Co., Ltd. (tunnel), with 0.84. This project had been in operation for 13 years as of 2016. At the beginning, its efficiency score was low, but it increased gradually. The improvement of sales and decrease of interest expenses annually had a positive effect on its efficiency score. The input levels for the project were ranked in the middle, but sales and cash flow as output factors were at a high level with middle traffic volume.

The second highest score went to Mun Hack Development Co., Ltd. (Incheon) (0.81); and the third, Mishiryung Area Development Co., Ltd. (0.80). These two projects had low input, and more than one input factor was relatively high.

In contrast, the projects with the lowest efficiency scores were Eulsukdo Bridge Co., Ltd. (Busan) (0.35); Machang Bridge Corp. (0.54); and Bukhang I'Bridge Co., Ltd. (Busan) (0.51). Three of these were outside the Seoul metropolitan area and had lower output levels given their input.

Table 9

Annual Efficiency Score Results by Project (Bridges/Tunnels)

DMU name/year	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean	CA GR	Rank
Bukhang I'Bridge Co., Ltd. (Busan)	0.51													0.51	-	11
Eulsukdo Bridge Co., Ltd. (Busan)	0.31	0.33	0.35	0.37	0.39									0.35	5%	12
GK Fixed Link Corp. (Busan-Geoje)	1.00	0.69	0.65	0.69										0.76	-9%	6
Ilsan Grand Bridge Corporation	0.58	0.66	0.66	0.75	0.82	0.90	1.00							0.77	8%	5
Incheon Bridge Co., Ltd.	0.56	0.58	0.65	0.73	0.82	1.00								0.72	10%	7
Machang Bridge Corp.	0.35	0.38	0.38	0.42	0.61	0.76	0.89							0.54	14%	10
Manwolsan Tunnel Co., Ltd. (Incheon)	0.80	0.59	0.64	0.69	0.71	0.69	0.71	0.48	0.32	0.34				0.60	-8%	8
Mishiryung Area Development Co., Ltd.	0.59	0.61	0.70	0.77	0.82	0.87	0.88	0.95	1.00					0.80	6%	3
Mun Hack Development Co., Ltd. (Incheon)	0.60	0.60	0.67	0.74	0.69	0.81	0.90	0.88	0.92	0.95	1.00	0.73	1.00	0.81	4%	2
Wonjecksan Tunnel Inc.	0.93	1.00	0.72	0.74	0.79	0.83	0.88	1.00	0.83	0.43	0.41			0.78	-7%	4
Woomyunsan Development Co., Ltd. (Tunnel)	1.00	0.62	0.65	0.69	0.76	0.78	0.87	0.90	0.94	1.00	1.00			0.84	0%	1
Yongma Tunnel Co., Ltd.	0.55													0.55	-	9
Mean	0.65	0.61	0.61	0.66	0.71	0.83	0.88	0.84	0.80	0.68	0.80	0.73	1.00		2%	

Projects with high efficiency scores were characterized by medium input levels and more than one item with a high output level.

3) T-test

a) Seoul Metropolitan Areas vs. Non-Seoul Metropolitan Areas

In the first hypothesis, it was predicted that Seoul metropolitan area projects would be more efficient than those in non-Seoul metropolitan areas. This hypothesis was based on the expectation that there would be more users for facilities near Seoul and that traffic volume and profit would be guaranteed, to some extent.

As a result of the t-test, the average value of efficiency in the Seoul metropolitan area was higher and significant at a 95% confidence level. Variance for the metropolitan area was narrower, and non-metropolitan areas had a larger deviation between projects.

Table 10

T-test Results (Metropolitan Areas vs. Non-metropolitan Areas)

	Seoul metropolitan	Non-Seoul metropolitan
Mean	0.747579102	0.614784512
Variance	0.020245549	0.033713533
Observations	13	18
Df	29	
t stat	2.174908496	
P(T ≤ t) two-tail	0.037935292	
t critical two-tail	2.045229642	

b) Bridges/Tunnels vs. Main Roads

The second hypothesis anticipated that main road projects would be more efficient than tunnels/bridges. This hypothesis drew from the expectation that tunnels and bridges would require more construction costs per km.

As a result of the t-test, the average value of efficiency for main roads was higher but not significant at a 95% confidence level.

Table 11

T-test Results (Main Roads vs. Bridges/Tunnels)

	Main roads	Bridges/tunnels
Mean	0.629724562	0.545469724
Variance	0.046694181	0.01837692
Observations	19	12
Df	29	
t stat	1.20507186	
P(T ≤ t) two-tail	0.237917553	
t critical two-tail	2.045229642	

C) MRG vs. Non-MRG

To determine if MRGs actually affected efficiency scores, cases with and without MRGs were compared. This analysis was based on efficiency scores calculated by distinguishing bridges/tunnels from main roads. If the ratio of MRG to sales was high, efficiency scores increased. If MRGs were received, efficiency scores decreased given a ratio of sales less than 30-40%.

Table 12

Efficiency Scores (Including MRGs vs. Excluding MRGs)

DMU name	MRG ratio to sales	Efficiency score (including MRG)(A)	Efficiency score (Excluding MRG)(B)	B-A
Wonjecksan Tunnel Inc.	119.31%	0.78	0.82	0.045
Manwolsan Tunnel Co., Ltd. (Incheon)	86.50%	0.60	0.65	0.049
Machang Bridge Corp.	61.53%	0.54	0.64	0.099
Bukhang I'Bridge Co., Ltd. (Busan)	45.09%	0.51	0.74	0.229
MunHack Development Co., Ltd. (Incheon)	33.94%	0.81	0.86	0.057
Ilsan Grand Bridge Corporation	25.75%	0.77	0.76	-0.008
GK Fixed Link Corp. (Busan-Geoje)	24.86%	0.76	0.93	0.169
Mishiryung Area Development Co., Ltd.	19.36%	0.80	0.67	-0.134

Woomyunsan Development Co., Ltd. (Tunnel)	19.31%	0.84	0.82	-0.019
Eulsukdo Bridge Co., Ltd. (Busan)	14.43%	0.35	0.31	-0.040
Incheon Bridge Co., Ltd.	14.29%	0.72	0.75	0.029
Yongma Tunnel Co., Ltd.	0.00%	0.55	0.42	-0.133
Daegu East Circulation Road Co., Ltd.	92.13%	0.41	0.52	0.107
Kwangju Ring Road Co., Ltd. (Section1)	77.28%	0.58	0.63	0.059
Kwangju Ring Road Co., Ltd. (Section3)	50.12%	0.75	0.82	0.065
New Airport Highway Co., Ltd. (Incheon)	45.96%	0.84	0.85	0.010
Daejeon Riverside Expressway Co., Ltd.	45.54%	0.77	0.79	0.019
New Daegu Busan Expressway Co., Ltd.	44.00%	0.65	0.66	0.012
CheonanNonsan Expressway Co., Ltd.	30.64%	0.81	0.68	-0.123
Seoul Beltway Corp.	17.16%	0.84	0.66	-0.175
Seoul-Chuncheon Highway Co., Ltd.	8.56%	0.75	0.46	-0.292
The Third Gyeongin Highway Co., Ltd.	7.80%	0.81	0.78	-0.029
Gyeonggi Highway Co., Ltd. (West Suwon-Pyeongtaek)	4.12%	0.57	0.33	-0.237
Gwangju Belt-Highway Inc. (Section 4)	3.92%	0.90	0.89	-0.007
GYEONGSU Highway Co., Ltd. (YongIn-Seoul)	1.55%	0.69	0.48	-0.213
Kyunggi South Road Co., Ltd.	0.00%	1.00	1.00	-
The2nd Seohaean Expressway Co., Ltd.	0.00%	0.80	0.52	-0.277
Namyangju Urban Expressway Co., Ltd.	0.00%	0.45	0.39	-0.060
The Gyeongnam Highway Co., Ltd. (Changwon-Busan)	0.00%	0.43	0.40	-0.036
Daegu South Circulation Road Corporation	0.00%	0.42	0.35	-0.063
Busan Ulsan Expressway Co., Ltd.	0.00%	0.30	0.18	-0.120

Additional t-tests were conducted to determine the characteristics of groups with high efficiency scores, including whether they had funds from financial investors, whether they were circulation roads in the city or outside, and whether they had operated for more than 10 years.

In this case, only operation period affected efficiency scores. Groups in operation for more than 10 years showed a higher average score (0.74) than other groups (0.60), with these scores significant at a 95% confidence level.

4) CAGR

On the other hand, since this analysis used time series data, additional examination of the Compound Annual Rate of Growth (CARG) is possible. The CARG of each project provides meaningful information if improvement has taken place from the beginning to the present. CARG was calculated using 3rd year efficiency scores and 2016 efficiency scores.

For the main roads group, projects with low average efficiency scores operating for less than 10 years returned a higher CARG: Namyangju Urban Expressway Co., Ltd.; The Gyeongnam Highway Co., Ltd. (Changwon- Busan); and Busan Ulsan Expressway Co., Ltd.

Three projects showed negative growth rates (Kwangju Ring Road Co., Ltd. (Section 1); the 2nd Seohaean Expressway Co., Ltd.; and Daegu East Circulation Road Co., Ltd.).

Table 13

CARG for Efficiency Scores by Project (Main Roads)

DMU name	Efficiency score in 3rd year	Efficiency score in 2016	Mean	Operating years by 2016	CAGR
Kyunggi South Road Co., Ltd.	1.00	1.00	1.00	4	-
Gwangju Belt-Highway Inc. (Section 4)	0.77	1.00	0.90	10	3%
New Airport Highway Co., Ltd. (Incheon)	0.61	1.00	0.84	16	4%
Seoul Beltway Corp.	0.58	1.00	0.84	11	6%
The Third Gyeongin Highway Co., Ltd.	0.68	1.00	0.81	7	8%
CheonanNonsan Expressway Co., Ltd.	0.52	1.00	0.81	14	6%
The 2nd Seohaean Expressway Co., Ltd.	0.84	0.75	0.80	4	-5%
Daejeon Riverside Expressway Co., Ltd.	0.53	1.00	0.77	13	6%
Kwangju Ring Road Co., Ltd. (Section 3)	0.44	1.00	0.75	13	8%
Seoul-Chuncheon Highway Co., Ltd.	0.59	0.97	0.75	8	9%

GYEONGSU Highway Co., Ltd. (YongIn-Seoul)	0.56	0.80	0.69	8	6%
New Daegu Busan Expressway Co., Ltd.	0.56	0.76	0.65	11	4%
Kwangju Ring Road Co., Ltd. (Section 1)	1.00	0.63	0.58	16	-3%
Gyeonggi Highway Co., Ltd. (West Suwon-Pyeongtaek)	0.45	0.68	0.57	8	7%
Namyangju Urban Expressway Co., Ltd.	0.37	0.57	0.45	6	11%
The Gyeongnam Highway Co., Ltd. (Changwon-Busan)	0.39	0.48	0.43	4	12%
Daegu South Circulation Road Corporation	0.37	0.46	0.42	4	12%
Daegu East Circulation Road Co., Ltd.	0.60	0.43	0.41	15	-2%
Busan Ulsan Expressway Co., Ltd.	0.22	0.43	0.30	8	12%

Meanwhile, the main roads group indicated a mostly upward trend, while the bridges/tunnels group could be divided into three categories: high growth (8-14%), medium growth (4-6%), and negative growth (-7-9%).

Table 14

CARG for Efficiency Scores by Project (Bridges/Tunnels)

DMU name	Efficiency score in 3rd year	Efficiency score in last year	average	Operating years by 2016	CAGR
Woomyunsan Development Co., Ltd. (Tunnel)	1.00	1.00	0.84	13	0%
Mun Hack Development Co., Ltd. (Incheon)	0.60	1.00	0.81	15	4%
Mishiryung Area Development Co., Ltd.	0.59	1.00	0.80	11	6%
Wonjecksan Tunnel Inc.	0.93	0.41	0.78	13	-7%
Ilsan Grand Bridge Corporation	0.58	1.00	0.77	9	8%
GK Fixed Link Corp. (Busan-Geoje)	1.00	0.69	0.76	6	-9%
Incheon Bridge Co., Ltd.	0.56	1.00	0.72	8	10%
Manwolsan Tunnel Co., Ltd. (Incheon)	0.80	0.34	0.60	12	-8%
Machang Bridge Corp.	0.35	0.89	0.54	9	14%
Eulsukdo Bridge Co., Ltd. (Busan)	0.31	0.39	0.35	7	5%

Ⅵ. Conclusion

6.1 Summary and Conclusions

The PPP market in the Republic of Korea has grown and developed into a stable and profitable financial market as a result of the government's systemic support and management (Kim et al., 2011). However, both negative and positive evaluations of the PPP system and market remain. At this point, addressing the current system to evaluate factors that contribute to the success or failure of projects is useful to inform effective future policy to improve the PPP system and market.

In preparation for this paper, a quantitative study was carried out using DEA from a financial perspective, assessing PPP road projects in the Republic of Korea in order to formulate practical, applicable implications for PPP policy. DEA enables the measurement of relative efficiency by estimating the producible set and boundary based on input and output data for each DMU when multiple input and output factors are involved. The resulting analysis provides direction as to how resources should be reduced or increased to enable better efficiency. When deciding on input and output factors, essential perspectives on PPP projects as not only infrastructure for the public but also PF were considered. The capacity of PF projects to generate cash is very important and should be sufficient to repay investors' principal and interest expenses. In this research, three input and three output factors were investigated: the input factors were operating cost, AMOR, and interest expense, while the output factors were CFOA, traffic volume, and sales.

Since PPP road projects represent more than half of the PPP market in the Republic of Korea, PPP road projects, especially those in operation for more than 3 years as of the end of 2016, were chosen for analysis. Samples included 13 tunnels and bridges, and 22 main roads. Roads composed of only tunnels and bridges were separated into different groups because of differences with general roads, such as road length and construction costs.

As a result of efficiency analysis using panel data, Kyunggi South Road Co., Ltd., was determined to be the most efficient among the 19 main road projects, with an efficiency score of 1. Woomyunsan Development Co., Ltd. (tunnel), from the group of 12 bridges/tunnels was assigned a score of 0.84. Unlike for the main road group, the longer they had operated, the more likely bridges/tunnels were to see an increased score. Projects with high efficiency scores had several attributes in common, e.g., a medium input level with more than one output of a high level. In addition, projects in the Seoul metropolitan area or receiving a higher ratio of MRG to sales tended to have higher efficiency scores.

This assessment offers clues regarding factors behind success and failure, yielding useful insights for future PPP policies. However, there are several limitations to this study. First, while focusing on financial aspects, input and output factors related to operational services such as accident handling speed, number of accidents, and satisfaction of users could not be considered. Second, although roads are main projects in the PPP market of the Republic of Korea, other project types such as railroads and ports should also be analyzed in further studies.

6.2 Policy Implications

First of all, the government should conduct feasibility studies more carefully and thoroughly, especially focusing on traffic volume estimation, before proceeding with new projects in local areas or non-Seoul metropolitan areas. As a result of a t-test, the average value of efficiency in the Seoul metropolitan area was found to be higher and significant at a 95% confidence level. Variance for metropolitan areas was narrower, and non-metropolitan areas had larger deviation between projects. This finding was highly influenced by demand estimation, rather than estimations for cost of construction or operation. It turned out that the lower efficiency scores for most projects in non-metropolitan areas indicated larger gaps between estimations for traffic volume and real traffic conditions, giving relatively lower mean of sales and CFOA than expected.

However, since estimating future profit and cost accurately is hardly possible, institutional devices and strategies are essential, highlighting the importance of such measures as periodically monitoring demand and tightening up internal supervision by the authority in charge. Under the current system, the estimated cost of projects tends to be adjusted to real cost, but estimated demand is maintained. However, by monitoring the demand gap between estimated values and real figures, the motivation to overestimate demand to enhance project feasibility will decrease if the private sector project representatives who overestimated the demand incur a penalty. Also, rigid internal supervision could decrease the likelihood of projects being carried out indiscriminately by public officials in charge.

Moreover, if government guarantees or subsidies are expected, incentive for the private sector to overestimate demand is generated. Based on a comparison of results for projects with and without MRG, higher MRG to sales ratios implied higher efficiency scores. This suggests projects with MRG received higher scores due not to efficiency but MRG itself. Therefore, the government would do well to reduce the burden of MRG payments by increasing SPCs' sales. Conscientiously managing MRGs so as to prevent moral hazards and motivate creation and efficiency for increasing sales from the private sector is the government's duty.

The government has been making an effort to reduce the fiscal burden by altering the subsidy payment mechanism from MRG to MCC. This attempt is encouraging as an indication of effort to pursue satisfying results for the government, new investors, and existing investors. Further measures are still needed to address the more involved issues identified above, however, and the understanding of the challenges to improving PPP efficiency as clarified through this study should be taken as grounds to consider policy initiatives related to more accurate estimation and diligent project oversight.

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