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The Revenue-Beta Model for Private Participation in Infrastructure

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Abstract: Private Participation in Infrastructure is a concept which involves the public and the private sectors working in cooperation and partnership to provide infrastructure and public services. The purpose of this study is to propose the Revenue-Beta Model of obtaining a financial discount rate for PPI projects, especially road-related projects implemented by a BTO scheme with the following assumption: The Korean government can be considered as a risk-averse investor that can build a portfolio with each toll plaza on the Korean expressways. The most significant issue in this research is whether it is reasonable and practical to apply the Capital Asset Pricing Model to get an appropriate financial discount rate for PPI projects. As an example, the model is applied to a real BTO project: the CN Expressway project.

Key Words: *beta, CAPM, financial discount rate, private participation in infrastructure*

1. INTRODUCTION

Private Participation in Infrastructure (hereafter PPI) is a concept which involves the public and the private sectors working in cooperation and partnership to provide infrastructure and public services. In other words, PPI means that a private entity can provide and manage (or operate) the construction and management of social overhead capital (SOC) such as roads, railways, harbors, environment facilities, and so forth. Through PPI, private entities can take part in one of the traditionally important and primary roles and responsibilities of the government. The necessity of the PPI program can be explained with two points. First, it has been proved empirically that the risk of government failure characterized by both the inefficiency of management and shortage of supply for infrastructure is higher than that of market failure characterized by shortage of supply and decrease of external effects. Second, as Korea moves towards a welfare society, it would be practically impossible for the government to provide suitable infrastructure by waging higher taxes on the already burdened citizens. As

a result of the rapid growth of the Korean economy, deficiency of infrastructure similar to that already experienced by developed countries has occurred. Thus, the Korean government has been trying to develop a PPI program as an alternative that can support a constant provision of infrastructure.

In Korea, the Private Participation in Infrastructure Act (hereafter PPI Act) was created in 1994 and considerably amended in 1998 in order to induce private capital investment in public infrastructure projects. The Korean PPI system implements largely four types of schemes: BTO (Build-Transfer-Operate), BOT (Build-Operate-Transfer), BOO (Build-Own-Operate) and BTL (Build-Transfer-Lease). Among them, BTO and BTL schemes are most often used. Furthermore the Korean government encourages private investment into infrastructure with various types of strong supports: financial supports (e.g. construction subsidy, minimum revenue guarantee), risk mitigation for foreign exchange rate risks, tax benefits, compensation termination, and infrastructure credit guarantee fund.

The purpose of this study is to propose a method of obtaining a financial discount rate for PPI projects, especially road-related projects implemented by a BTO scheme with the following assumption: The Korean government can be considered as a risk-averse investor that can build a portfolio with each toll plaza on the Korean expressway. The most significant issue in this research is whether it is reasonable and practical to apply the Capital Asset Pricing Model (hereafter CAPM) to get an appropriate financial discount rate for PPI projects.

In this paper, which is based on the risk concept, Markowitz's portfolio theory is introduced as the foundation of the CAPM. Second, assumptions and results of the CAPM are discussed with a basis on Markowitz's portfolio theory. Third, similarities between stock market and a market comprising toll plazas on the Korean expressways are discussed, and whether it is reasonable and practical to employ CAPM for obtaining a proper financial discount rate is explained. Fourth, a new model for getting a financial discount rate is established on the basis of the above research. Then as an example, the model is applied to a real BTO project: the CN Expressway project. Last, practicalities and limitations of the proposed method are discussed, and subjects for further studies are mentioned.

2. MARKOWITZ'S PORTFOLIO THEORY

2.1 Assumptions

When selecting a portfolio, Harry Markowitz suggests using the "expected returns-variance of returns" rule concerning the stage to choose optimal portfolio based on the relevant beliefs about the future performances of available securities. Markowitz's portfolio theory is based on the following assumptions;

1) There are a lot of investors, each with wealth that is small compared to the total wealth of all the investors; so that investors are price-takers not price-makers.
2) All investors are risk-averse, and will try to maximize their expected utilities.
3) All investors are rational mean-variance optimizer, meaning that they choose the portfolio with higher expected return when given a choice between two portfolios with identical variances, and they choose the one with lower variance when given a choice between two portfolios with identical expected returns.
4) There is a risk-free rate at which an investor may either lend or borrow money.

5) All investors plan for one identical holding period.
6) All investors pay no taxes on returns and no transaction cost.

2.2 Results

To obtain the efficient frontier in the case of existing risk-free assets, the first step is to construct the efficient frontier with N risky stocks. The second step is to select the optimal portfolio lying on the efficient frontier obtained by the first step; the straight line emanating from the risk-free asset and the optimal portfolio should dominate any other straight lines. The optimal portfolio is the tangent portfolio T in Figure 1 whose capital allocation line(hereafter CAL) is the steepest slope; which means that CAL of tangent portfolio T gives the highest reward-to-risk ratio (or reward-to-variability ratio) since the slope of CAL is the expected excess return, $E(r_i)-r_f$, per unit of risk, σ_i. Finally, the efficient frontier with the existence of the risk-free asset is the straight line emanating from the risk-free asset and is the tangent portfolio T, illustrated with the sky-colored straight line in Figure 2 and represented as follows:

$$E(r_P) = r_f + [\frac{E(r_T)-r_f}{\sigma_T}] \cdot \sigma_P \qquad (2.1)$$

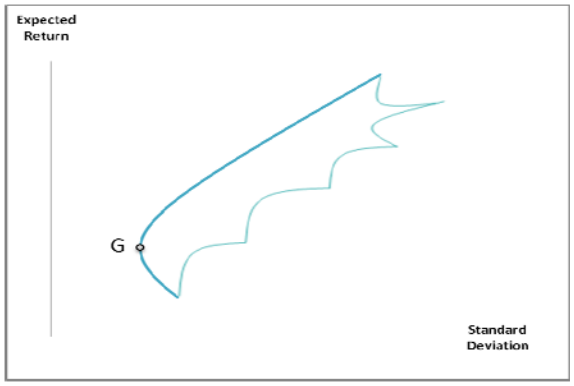

Figure 1 Feasible and efficient frontier

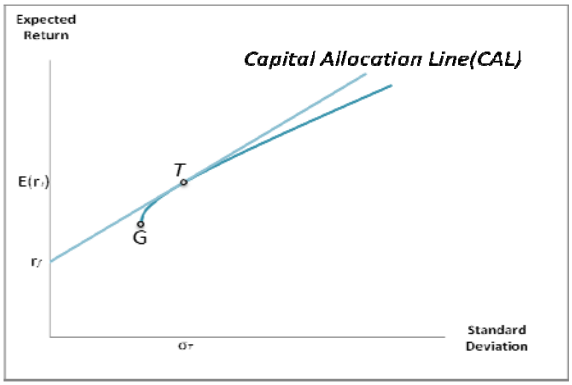

Figure 2 The capital allocation line

3. THE CAPITAL ASSET PRICING MODEL

3.1 Assumptions

The capital asset pricing model (hereafter CAPM) gives a precise prediction of the relationship between the risk of an asset and its expected return; i.e. to reveal the process for determining the expected return on a risky asset is to see how to determine its equilibrium price. The CAPM was developed by William Sharpe, John Lintner, and Jan Mosin based on Markowitz's Portfolio Theory. Therefore, the assumptions of the CAPM include the assumptions for the portfolio theory, with two more important, additional assumptions:

1) There is a perfect market for securities in a fixed supply, meaning that securities prices are affected by investors' decisions of the securities rather than suppliers' decisions.
2) All investors have homogeneous expectations or beliefs, meaning that they have the same

conceptions regarding the expected returns, variances and covariances of securities under free and instantly available information.

In particular, the second assumption has played a significant role in the development of Markowitz's portfolio theory to the CAPM.

3.2 Results

Under the homogeneous expectations, the tangent portfolio T would be the market portfolio M in equilibrium. Hence, the efficient frontier (or CAL) can be made with the market portfolio M and a risk-free asset; this efficient frontier is called the capital market line (hereafter CML) in Figure 3 and represented as follows:

$$\frac{E(r_i)-r_f}{Cov(r_i,r_M)}=\frac{E(r_M)-r_f}{{\sigma_M}^2} \tag{3.1}$$

Modifying Equation (3.15) in terms of the expected return on an individual security,

$$\begin{aligned} E(r_i) &= r_f+[E(r_M)-r_f]\cdot\frac{Cov(r_i,r_M)}{{\sigma_M}^2} \\ &= r_f+[E(r_M)-r_f]\cdot\beta_i \end{aligned} \tag{3.2}$$

Equation (3.1) represents the relationship between the beta of a security i and its expected return in equilibrium, which is the capital asset pricing model and illustrated in Figure 4. The blue solid line is the security market line (hereafter SML). The SML means that the expected return on a stock i is determined by adding the risk-free interest rate and the risk premium; the risk premium is determined by multiplying market risk premium by the beta, measure of the systematic risk. In other words, the beta of a security is the only significant factor when determining its expected return. Moreover, the expected return on a security i is linearly related to its beta.

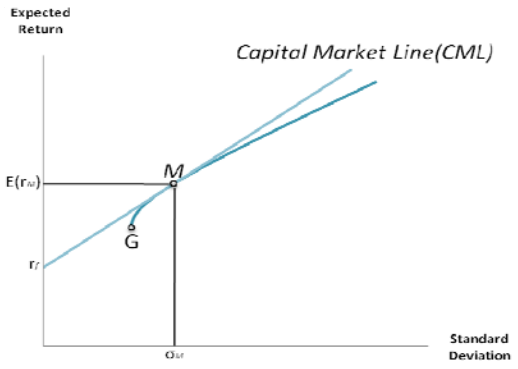

Figure 3 The capital market line

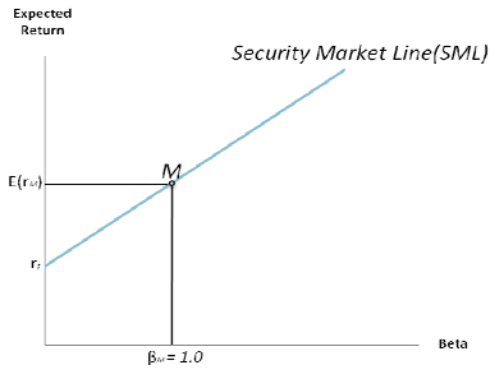

Figure 4 The security market line

4. THE REVENUE-BETA MODEL

There exists a risk that the actual revenue of a road-related PPI project under a BTO scheme will turn out to be much less than the projected revenue prescribed in the contract. In this case, the Korean government guarantees a fraction of the projected annual revenue with a proper earning rate. All previous researches on determining the earning rate of a PPI project have taken approaches from a firm's viewpoint. In this paper, however, the earning rate of a PPI project will be expressed as a function of the systematic risk of revenue, implying that this approach starts from the rational risk-averse investor's viewpoint with the CAPM. Hereafter, this new approach will be referred to as the Revenue-Beta Model.

4.1 Assumptions

The Revenue-Beta model based on the CAPM requires the following basic assumptions:

1) There are enough toll plazas on the expressways in Korea to form a market with similar characteristics of a stock market.
2) Each individual toll plaza is regarded as a company listed on a stock market and operated by the private.
3) The Korean Government is a risk-averse investor and price-taker in the toll plaza market.
4) The Korean Government is a rational mean-variance optimizer and can construct a portfolio of toll plazas with the risk-free asset.

In the first and second assumptions, the revenue of toll plazas generated by the freeway traffic volume is similar to the stock price of a company listed on the stock market, since the revenue of an individual toll plaza is a unique representative value that shows all economic characteristics corresponding to the stock price. Moreover, provided that the traffic volume is concentrated on a specific expressway, the relative revenue performance of toll plazas involved in the expressway will be better than that of the other plazas. This phenomenon is analogous to the flow of money from one industry to another industry in the stock market; the toll plazas within a large expressway can be considered as companies composing an industry in the stock market. Consequently, it is reasonable to regard each toll plaza as a company listed on the stock market. The third and forth assumptions will be discussed with the Revenue-Beta model.

4.2 Description of the Revenue-Beta Model

In the previous section, we have shown that each toll plaza can be regarded as a company listed on the stock market, and the revenue of a toll plaza as the stock price. The third and forth assumptions also play a significant role in connecting the Revenue-Beta Model with the CAPM. The Korean government as a risk-averse investor and a rational mean-variance optimizer can construct a market portfolio M in the toll plaza market according to Markowitz's analysis. Also, there is only one investor, the Korean government, in the market consisting of toll plazas whose characteristic is almost homogeneous as an asset. Thus, an important assumption in the CAPM, the homogeneous belief, is more fitted in the Revenue-Beta model than in the CAPM.

By using the beta based on revenue, an appropriate earning rate is obtained in equilibrium and expressed as follows:

$$ER_i = r_f + Risk\ \text{Premium}\ \cdot \beta_{R_i} \tag{4.1}$$

where ER_i is the earning rate of a toll plaza i and β_{R_i} is the systematic risk of the toll plaza i. Recalling the CAPM, $E(r_i) = r_f + [E(r_M) - r_f] \cdot \beta_i$, the expected return on a stock is determined by the risk-free interest rate, the market risk premium, and its beta. In Equation (2.1), a proper earning rate is also determined by the risk-free interest rate, the risk premium of market portfolio M in the toll plaza market, and the revenue-related beta. In particular, the measure of risks in the Revenue-Beta Model is the systematic risk in terms of the arithmetic return on the revenue for the holding period(hereafter ARR); i.e. $\beta_{R_i} = \frac{Cov(ARR_i, ARR_M)}{Var(ARR_M)}$.

One may have doubts about the second assumption, meaning that the ARR of each toll plaza i can be a measure of the expected rate of return on each stock i. In Ismail and Kim (1989), there was some evidence that the cash flow beta in accounting betas had the highest correlation with the market risk as well as strong explanatory powers. Because the Revenue-Beta is similar to the cash flow beta, it is plausible that the Revenue-Beta be qualified as a measure of the systematic risk in the toll plaza market.

5. APPLICATION THE REVENUE-BETA MODEL

5.1 Data

The CN Expressway project is the first PPI implemented by the BTO. In the contract, the Korean government guarantees 80% of the estimated revenue at maximum. In order to apply the Revenue-Beta model to the CN Expressway project, the daily revenues of every toll plaza on the Korean expressway except for the Incheon Airport expressway are obtained from the data set constructed by the Korean Freeway Corporation: 263 toll plazas on the Korean expressway. The data covers the period Jan. 1, through Nov. 30, 2008.

Table 1 The regional HQs and the number of toll plazas

Regional HQ	# of tall plazas
Gyeonggi	41
Gangwon	32
Chungcheong	45
Gyeongbuk	41
Gyeongnam	51
Honam	53
CN Expressway	1
Total	264

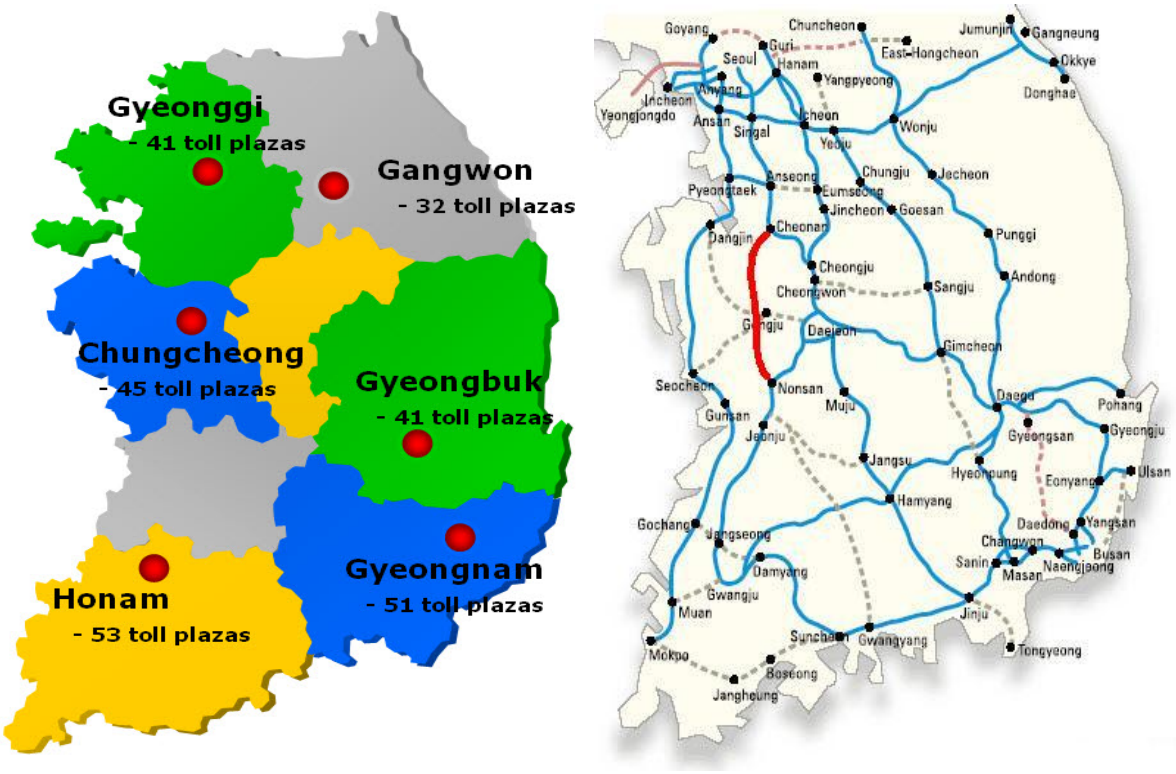

Figure 5 Regional headquarters and Korean expressway network

5.2 The Empirical Results

In this section, the empirical results will be presented. The first step is to estimate the Revenue-Beta of the CN Expressway by using the time-series regression each year as represented as follows:

$$ARR_{it} = a_i + b_i ARR_{Mt} + e_{it} \tag{5.1}$$

where b_i is the Revenue-Beta of toll plaza i each year and e_i is the residual term with $E(e_i) = 0,\ Cov(r_M, e_i) = 0,\ Cov(e_i, e_j) = 0$. The statistics of the Revenue-Beta of the CN Expressway from 2003 to 2008 are tabulated in Table 2, and plotted in Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12.

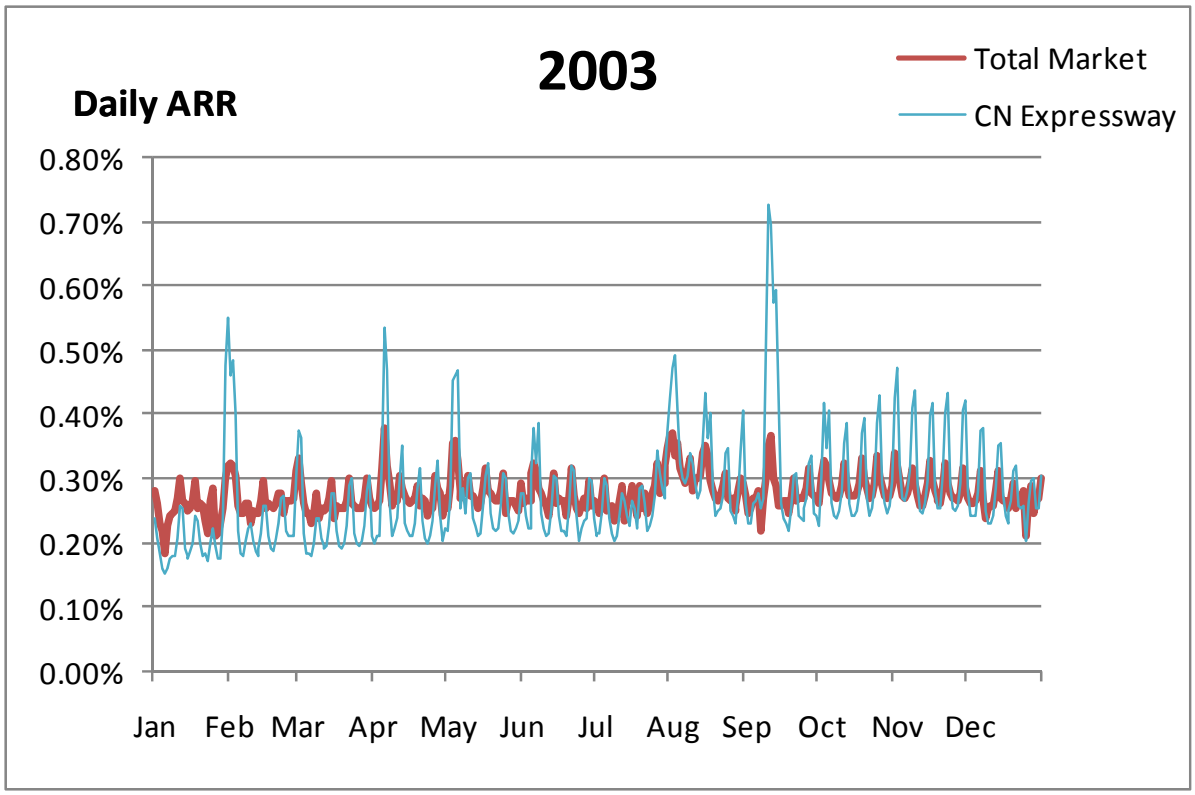

Figure 6 Daily ARR of the CN Expressway and total market in 2003

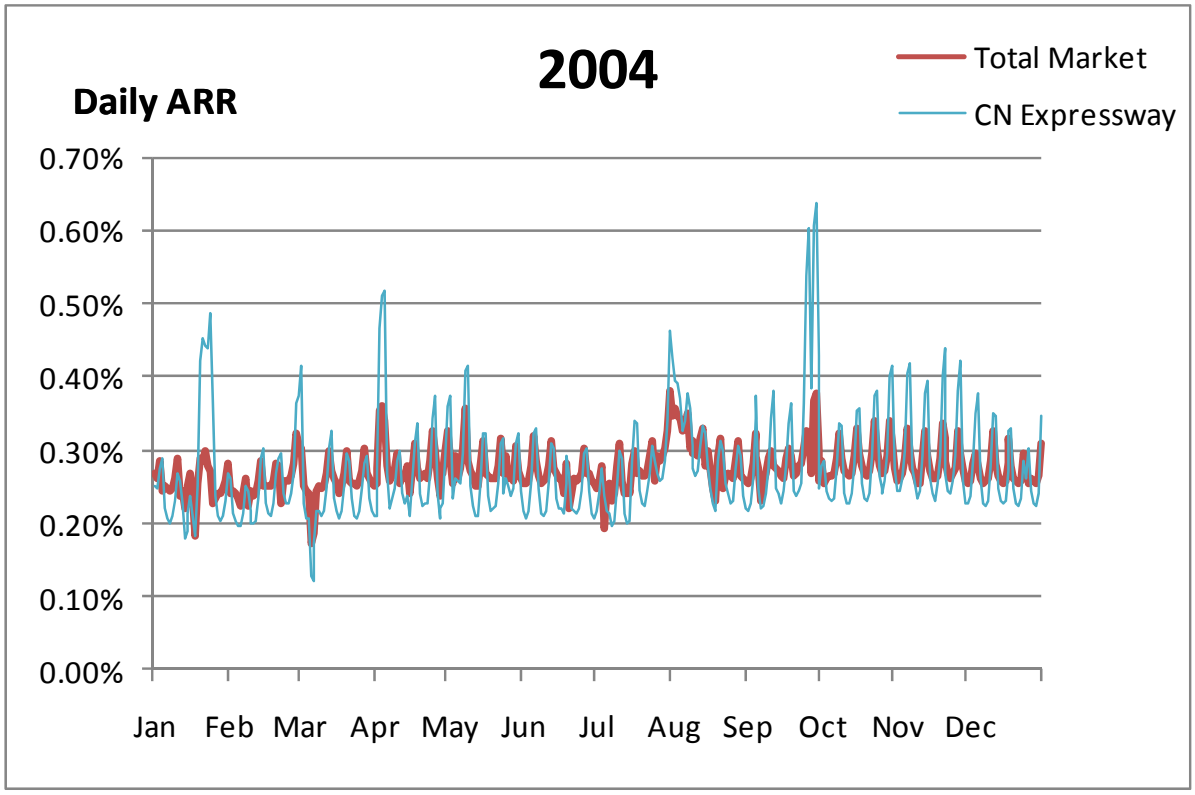

Figure 7 Daily ARR of the CN Expressway and total market in 2004

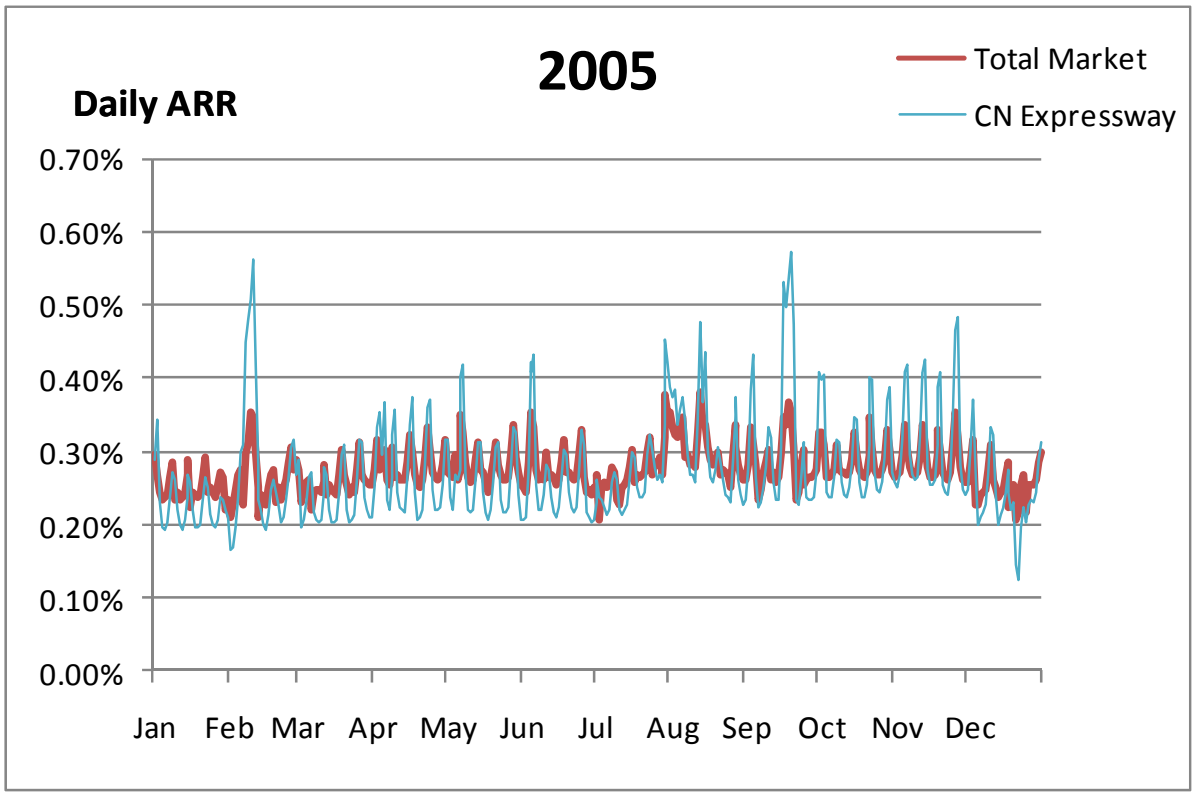

Figure 8 Daily ARR of the CN Expressway and total market in 2005

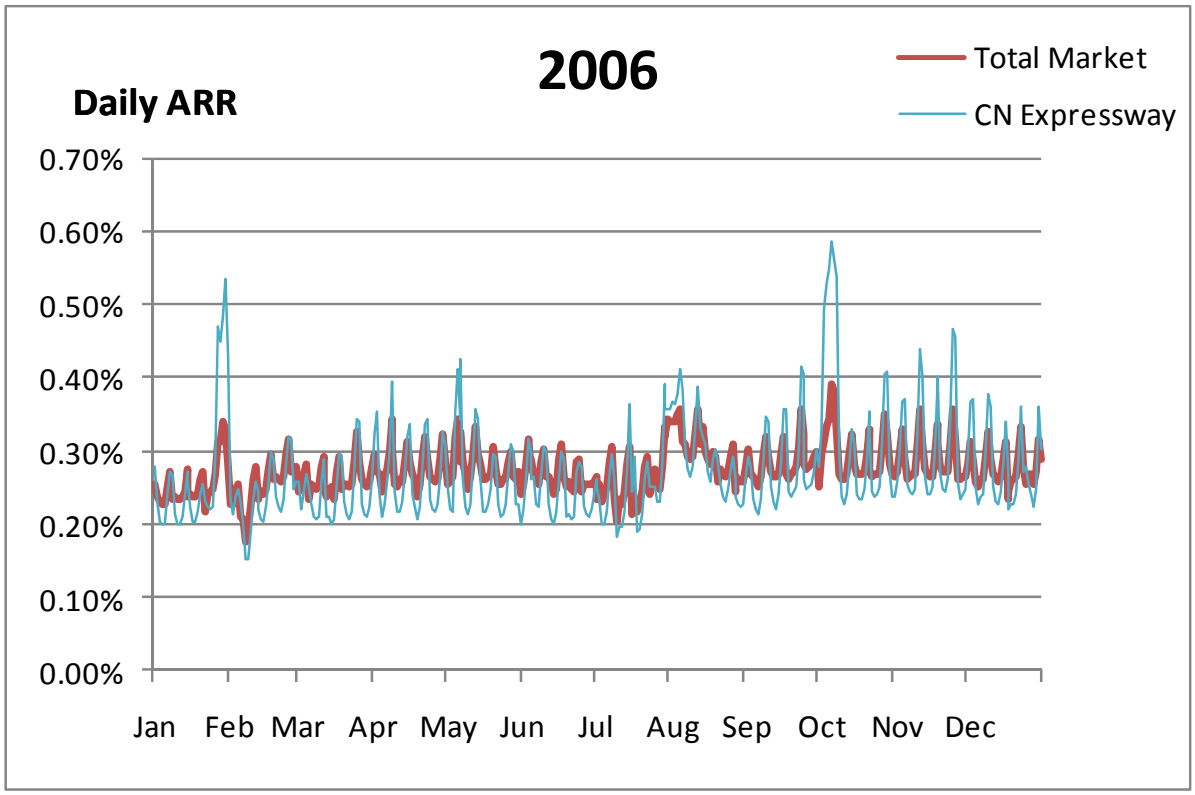

Figure 9 Daily ARR of the CN Expressway and total market in 2006

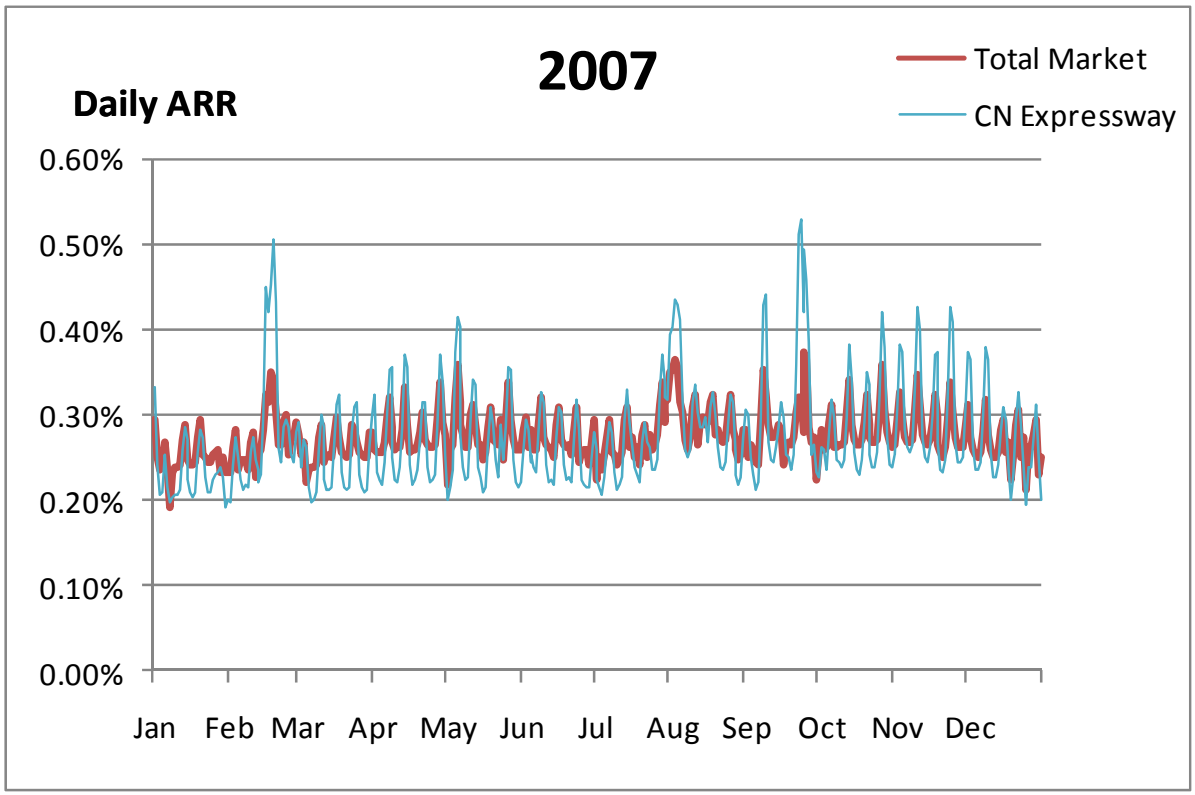

Figure 10 Daily ARR of the CN Expressway and total market in 2007

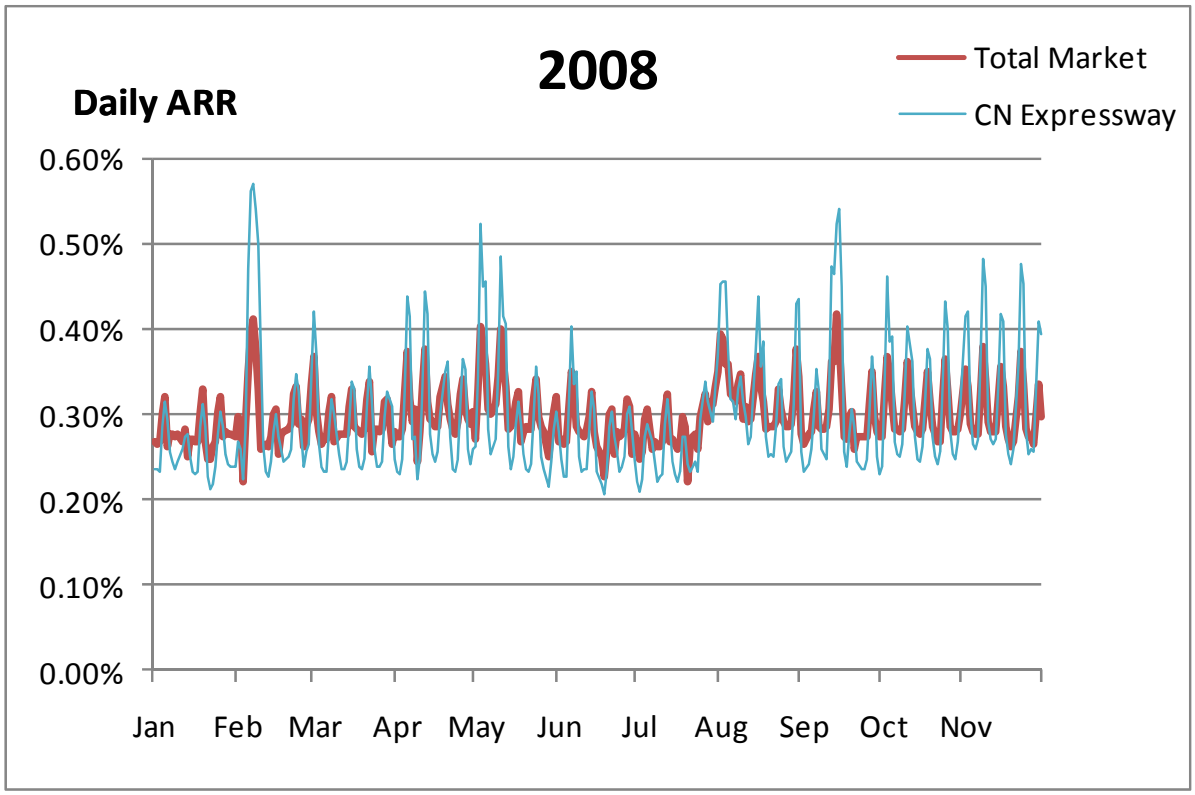

Figure 11 Daily ARR of the CN Expressway and total market in 2008

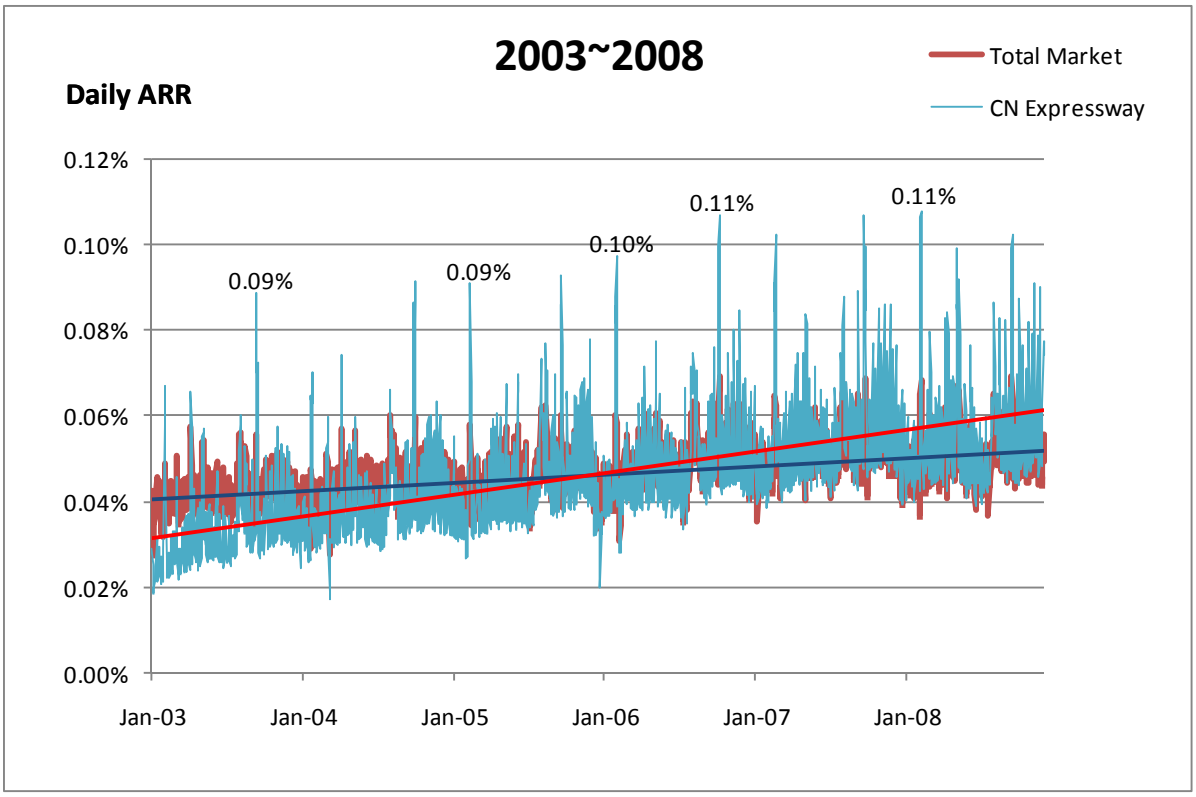

Figure 12 Daily ARR of the CN Expressway and total market in 2003-2008

As indicated in Table 2, no solid evidence of the Revenue-Beta of the CN Expressway having a trend over this period can be found. However, according to Figures 6-11, the annual change of the daily ARR shows a pattern similar to that of the toll plaza market, which implies that the annual daily traffic on the expressway has an outstanding pattern because the daily revenue of a toll plaza is closely related to the daily traffic. Figure 12 illustrates the growth rate of the daily ARR is positive; which is a reasonable result, because the Korean economy continues to grow and the number of vehicles in Korea is increasing. Furthermore, as known by Figure 12, we can observe that the overall growth rate of the CN Expressway, red solid line, is higher than the growth rate of the total toll plaza Market, blue solid line; i.e. it seems evidence that CN Expressway has a potential to obtain relative revenue comparing with other toll plazas.

Table 2 Summary statistics and the Revenue-Beta from 2003 to 2008

	2003	**2004**	**2005**	**2006**	**2007**	**2008**
Revenue Beta	2.274	1.912	1.965	1.824	1.853	1.909
Adj. R^2	0.611	0.615	0.731	0.717	0.731	0.796
Std. Error	0.000513	0.000447	0.000375	0.000368	0.000322	0.000328
t-statistics	23.95	24.17	31.50	30.34	31.49	36.06
p-value	1.06E-76	1.09E-77	6.99E-106	1.34E-101	7.58E-106	4.94E-117

6. Conclusion

In this paper, the Revenue-Beta Model is suggested as a new approach to obtain an appropriate financial discount rate for PPI projects. This model is developed from the CAPM which is a model to explain the relationship between the risk of an asset and its expected return in equilibrium. At first, this model starts from the following assumptions: The toll plaza market is very similar to the stock market and each toll plaza can be considered a company listed on the stock market. The Korean government is a rational risk-averse investor who can construct a portfolio with each toll plaza on the Korean expressway. In particular, the ARR of a toll plaza can be used as the rate of return on a stock. The Korean government, hence, can build a market portfolio M as well as obtain a proper earning rate of a toll plaza with the risk-free asset. The revenue-beta is measure of the systematic risk of a toll plaza, so an appropriate earning rate is determined by the risk-free interest rate, the risk premium of market portfolio and the revenue-beta.

By apply the Revenue-Beta model to a real project, CN Expressway, the revenue-beta is more than 1; it means that reaction of the CN Expressway is more sensitive than movement of the total toll plaza market. Therefore, the Korean government can compensate with the earning rate using the revenue-beta of the CN Expressway when supporting the fiscal resource.

The Revenue-Beta model can provide a benchmark to the Korean Expressway Corporation, when supporting operating revenue on a toll plaza owned by private. And the Revenue-Beta model can apply to a PPI project similar to a road-rated infrastructure; i.e. its market should be regarded as stock market as well as consists of enough assets to induce the diversification effect.

In this paper, risk premium of market portfolio is not given, since risk premium is determined when the Korean government contracts with a private sector. Thus, further research should be conducted to find methods to output a rational and appropriate risk premium in the Revenue-Beta model. Once the risk premium would be obtained through a certain method, the Korean government can get an appropriate social discount rate based on systematic risk and make an effective budget based on taxes.

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