Construction Management & Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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To cite this article: Anthony D. Songer , James Diekmann & Roger S. Pecsok (1997) Risk analysis for revenue dependent infrastructure projects, Construction Management & Economics, 15:4, 377-382, DOI: 10.1080/014461997372935

To link to this article: https://doi.org/10.1080/014461997372935

Published online: 21 Oct 2010.

Construction Management and Economics (1997) **15**, 377–382

NOTE

Risk analysis for revenue dependent infrastructure projects

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Received 6 May 1996; accepted 16 January 1997

Recent trends in the construction industry indicate continued use of alternative procurement methods such as design-build, construction management, build-operate-transfer, and privatization. Increased use of these evolving methods produces higher levels of uncertainty with respect to long term performance and profitability. The uncertainties inherent in implementing new procurement methods necessitate investigation of enhanced methods of pre-project planning and analysis. This is particularly true for revenue dependent privatization projects such as toll roads. Poor initial performance of toll road projects suggests traditional methods of project analysis are inadequate. Sustaining investor and stakeholder support of privatized revenue dependent projects is dependent upon successful financial performance. Enhanced risk analysis tools provide improved information for pre-project decision making and performance outcome. One such risk analysis method is the Monte Carlo. Monte Carlo methods are especially useful in evaluating which of several uncertain quantities most significantly contributes to the overall risk of the project. This paper demonstrates a Monte Carlo risk assessment methodology for revenue dependent infrastructure projects.

Keywords: Project finance, Monte Carlo, privatization, risk analysis, computer

Introduction

Privatization is increasingly being investigated as an appropriate delivery mechanism for infrastructure projects (Gomez-Ibanez *et al.*, 1991; Helm and Thompson, 1991; Schaevitz 1993; Tiong 1994a; Dias and Ioannou, 1996; ENR, 1996a,b,c). As risk exposure of project participants increases it becomes necessary to develop new approaches for determining the feasibility of projects. One example of privatized infrastructure projects requiring such feasibility analysis is toll roads. Current toll road projects have gained widespread attention for their sluggish initial performance (PWF, 1990; ENR, 1995a,b, 1996d; Feldman, 1995). Although the long term performance of privatization projects is unknown, the continued use of this method for delivering projects is jeopardized by the poor initial results. Stakeholders of toll road projects currently rely on project financial statements to make investment decisions. The information contained in the financial statement generally does not include appropriate assessment of project risks necessary for adequate investment decisions in such an uncertain environment. The methodology discussed in this paper suggests improved investment decisions will follow from more knowledgeable assessments of project risks. Improved investment decisions will lead to improved project selection which in turn results in improved project performance. Improved project performance sustains future investment enthusiasm in the new procurement method.

This paper suggests the use of a Monte Carlo risk analysis technique to enhance traditional decision making methods. Specifically, this paper provides a background of privatized toll road financing and risks, introduces the Monte Carlo technique and associated risk model, and demonstrates the process through a detailed toll road case study.

Privatized toll road financing

Project financing is a popular mechanism for funding toll road projects. 'Project financing' describes the methods which lenders use to finance the construction of new projects based on the anticipated revenue stream generated by the project (Castle, 1975). Toll road project financing mechanisms generally include some combination of debt and equity.

Equity participation in project financing includes stock purchases and general and limited partnership capital contributions. The amount of equity contribution often is indicative of the value placed on the project by the project promoter. Equity participation often determines the amount of debt the project can service, the amount of contingency available, and reduces the risk of insufficient funds for construction. The range of equity participation varies from project to project. Research illustrates a common equity range of 15–30% on nonrecourse project financing (Tiong, 1994b).

The most typical component of project financing is debt: specifically, senior debt. Senior debt is that debt that is not subordinate to other loans or equity. Sources of debt financing include commercial banks, leasing companies, insurance companies, pension funds, and governmental bonds.

Current toll road debt financing occurs primarily through bond issues. Investment and planning decisions for toll road projects depend greatly on the financial statement commonly known as the preliminary official statement. The official statement provides an in-depth description of the project for potential investors or bond holders of the project. The analysis found in the official statement is a result of studies conducted to predict revenue and operating expenses for the duration of the bond.

The cornerstone of the official statement is a summary of the Fixed Rate Senior Bonds' debt coverage throughout the life of the toll road project. Fixed Rate Senior Bonds are the principal financial component of the project. Debt coverage is defined as the ratio of revenue over the required debt service, and often is used by those in the financial community as the basis for evaluating projects. Due to its importance to the financial community, debt coverage calculations must be beyond reproach. Expected population growth, interest rates, toll revenues, operating expenses and commercial development are some of the factors that contribute to the debt coverage projections for any given year.

One difficulty with traditional debt coverage calculations is that the values used in the various scenarios are 'point values' for any given year and do not include any evidence of how likely these values are to occur. Additionally, traditional debt coverage calculations do not identify the critical variables contributing most to project risk.

Privatized toll road risk

Although a multitude of discussions on toll road risk exist, they are generally limited to categorization of risks (Castle, 1975; Marple, 1977; Hoffman, 1989; Garnett, 1992; Woody and Pourian, 1992). Risk categories often are identified with project phases. These include (i) development (technology, permitting, inflation, credit, and bid risks), (ii) construction (completion, cost overrun, political risks), (iii) operation (performance, cost overrun, liability, equity resale risks), and (iv) ongoing (interest rates and currency risks) (Beidleman *et al.*, 1990; Garnett, 1992).

While various permutations of scenarios and risk events are incorporated into the official statement revenue projections, they are used only to generate one instance of a revenue projection and they are not incorporated into the remainder of the project evaluation. However, the variables used in these financial calculations are highly interdependent. For example, high interest rates would affect growth in the project's geographical area, thus causing a decrease in projected revenues. Increasing interest rates also affect the interest earnings on the project's reserve accounts, which increases project revenues.

To develop accurate debt coverage distributions, internal and external project risks must be introduced into the debt coverage calculations. Internal risks are the variabilities that exist within the official statement to evaluate the projected debt coverage for any given year. An example of an internal risk is the revenue projection for any given year. External risks are not found in the official statement but may have significant effects on financial parameters. For example, and external risk may be the price of oil (which may affect driver behaviour) or the rate of inflation (which may affect investor behaviour) throughout the life of the bond.

Advanced decision making tools such as Monte Carlo address the issues of variability, criticality, interdependence, and external impacts, enhancing and extending traditional project assessment techniques.

Risk analysis: a Monte Carlo approach

A Monte Carlo risk assessment is a method of evaluating all the permutations of uncertain events that might impact the projected debt coverage for each year of the project life. The inputs required for the Monte Carlo analysis are distributions for the significant input variables that enter into the debt coverage calculation. These inputs are such items as the highway ridership, the toll generation, and the interest earnings on reserve funds. The probability distributions, sensitivity analysis, correlations, and external variables permitted by Monte Carlo address the shortcomings of traditional project assessment techniques previously noted.

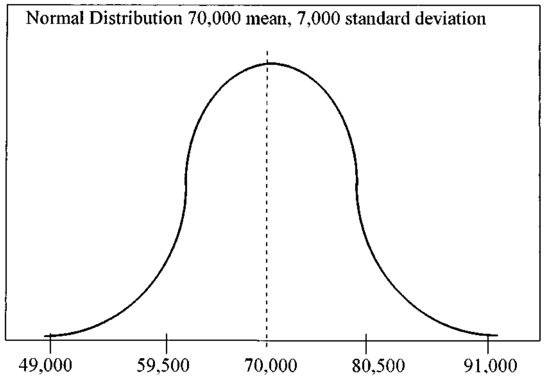

Figure 1 Number of toll transactions for the year 2002

Probability distributions

In a Monte Carlo analysis the traditional single-point estimate is replaced by a distribution of probable values. For instance, in the case study's official statement, the interest earned on the capitalized interest account is assumed to be 6.4%. A Monte Carlo based risk model allows variability for this value. For example, this number might vary between 5.0% and 7.5% with a more likely chance that it is less than 6.4%. Other key variables in the analysis, e.g., revenues or operating expenses, can be represented in a similar fashion. Figure 1 illustrates a distribution for common variables in a toll road debt coverage calculation.

A Monte Carlo analysis iteratively samples values from the associated ranges. During a Monte Carlo analysis, values from throughout the given range for each variable are used to calculate the debt coverage value for each year of the project's life. Upon completion, a probability distribution for each year is obtained.

Sensitivity analysis

Sensitivity analysis techniques provide guidance during the interative process of model development. Each model provides a sensitivity analysis which may be used to identify those variables that are contributing most to the overall risk level of the project. The input variables that contribute most to the project risk then become candidates for further investigation on how to narrow the range of expected values for them and, consequently, the forecast values. One-way sensitivity analysis using tornado diagrams identifies the range of change a variable may incur given a specific change in that variable. Sensitivity analysis techniques in Monte Carlo are illustrated in Figure 3 discussed in the case study section of this paper. A general discussion of sensitivity analysis is provided in Clemen (1991).

Variable correlation

Modern Monte Carlo applications extend traditional analysis by allowing variables in the analysis to be correlated with one another. The use of correlations among the project variables allows a more sophisticated modelling approach. For example, if the highway ridership in year N is lower than anticipated, it is reasonable to assume that ridership in year $N+1$ will likewise be lower than anticipated. In other words, it is unlikely that a year that experiences poor ridership will be followed by one that experiences better than expected ridership. An improvement in ridership from one year to the next would probably be gradual. One can model this behaviour by correlating the ridership in year $N+1$ with year N. Similarly, interest rates operations costs and other annual variables can be modelled using correlation between successive years.

Some project variables are inversely or negatively correlated with one another. For example, the toll charge for any future year may be treated as an uncertain variable. However, it is reasonable to assume that if the toll rate is higher than anticipated the ridership will be less than anticipated. The inverse relationship between these variables may be modelled using negative correlation coefficients.

External variables

Using advanced Monte Carlo techniques one can model the impact of external, global variables (or risks) on the debt coverage calculation. The inflation rate is one such global variable. The inflation in the general economy for any given year has a profound impact on the debt coverage calculation. The inflation rate impacts both interest rates on moneys the project must borrow and on investments the project has made. The inflation rate also affects the cost of construction activities and operations costs.

In summary, Monte Carlo methods can be employed to do much more than evaluate the uncertainty of the many variables that are used in the debt coverage calculation. Monte Carlo methods can be used to model complex causal and time-dependent relationships between variables. A toll road case study is provided to illustrate these extended capabilities. Case study values were normalized for purposes of confidentiality.

Case study

Project financing occurred through revenue bonds to the amount of $1 720 800 000. The project franchise period runs from the start of the design construction phase in 1996 through the final amortization of the revenue bonds in 2034. The official statement provides financial projections for three types of debt coverage; these are referred to as types I, II and III debt coverage. Type I debt coverage is simply the ratio of the net revenue projections for the year (including operating expenses) over the required debt service for the fixed rate senior bonds. The type II coverage is similar but includes also the interest earnings from the reserve accounts for the given year. The type III coverage is the same as type I but the debt service requirements include the fixed rate junior bond obligations. This paper addresses only the type I coverage.

Many assumptions are needed to arrive at the revenue bonds debt coverage projections. Estimates of highway ridership, toll levels, construction and operations costs, interest rates and earnings on reserve accounts are all factored into the debt coverage calculation. A Monte Carlo model can be used to test and validate the importance of these assumptions. In this study, the basic debt coverage calculation was reproduced as a computerized spreadsheet that was, in turn, used as the basis of the Monte Carlo analysis.

One proven method of developing Monte Carlo analyses is to approach model development iteratively. An effective starting point for an iterative Monte Carlo analysis is to create a simple model that contains none of the time dependent or causal relationships that were previously described. The preliminary model simply evaluates the impacts of the various variables included in the debt coverage calculation. This first simple model provides a basis for subsequent more comprehensive models.

The primary risks identified in this model are (a) number of toll transactions for a given year, (b) average annual toll rates, (c) annual operating expenses, (d) construction costs, (e) construction duration, and (f) interest rates. A total of 126 separate distributions were needed to represent these risks over the entire life of the risk analysis (see Table 1).

Table 1 Risk categories: preliminary model

Risk	Number of asumptions
Number of toll transactions	40 (one/year)
Average toll rates	40
Operating expenses	40
Interest rates	4
Construction cost and duration	2

Four debt coverage estimates are calculated in this first model. The four values are estimates of type I debt coverage evaluated for the years 2003, 2005, 2007 and 2020. The year 2003 is two years after the scheduled date of completion and represents the first year it is projected that the debt service needs to be covered. Consequently, the years 2003, 2005 and 2007 were chosen to represent the first five years of stabilization, and presumably those of the most interest to investors. 2020 was chosen to represent the long term life of the bond.

One result that is available from a Monte Carlo analysis is a frequency distribution. A frequency distribution is a valuable aid in the analysis because it provides a visual representation of the range of possible outcomes. The frequency distribution for the year 2003, the first year that it is required to pay the debt service from revenues, is displayed in Figure 2. This distribution represents the range of predicted outcomes for the debt service coverage at year 2003 for the senior bonds. Similar output is available for each of the other three other estimates.

This result shows a mean value for debt coverage of 1.3 times. The mean value of 1.3 is exactly the same as the non-risk based estimate of type I debt coverage. However, the Monte Carlo results also provide an estimate of the worst case debt coverage (approximately 1.0 times) and the best debt coverage (approximately 1.5 times).

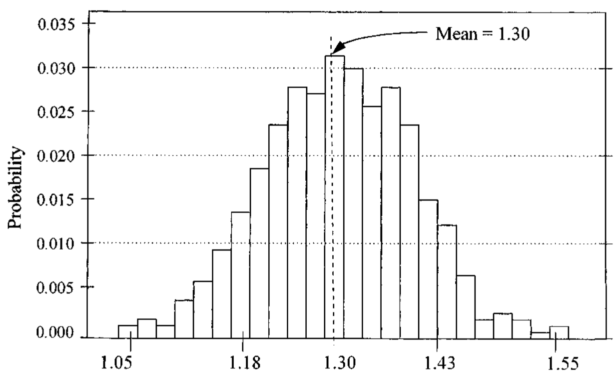

Figure 2 Frequency distributions – debt coverage (simple model) for the year 2003

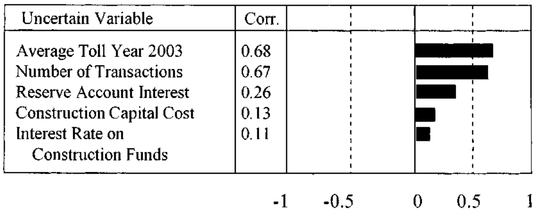

Figure 3 Sensitivity analysis – bond coverage for the year 2003 (measured by rank correlation)

Another result from the Monte Carlo procedure is a sensitivity analysis. A sensitivity analysis indicates the variables that have the greatest impact on the debt coverage calculations. Using this analysis, one can determine which risks need further study. By spending more effort evaluating the range of risks for the most sensitive variables, one may mitigate some of the project risks. Risk mitigation is often one of the most useful outcomes from the risk model. The sensitivity analysis for the year 2003 is shown in Figure 3 and confirms that the toll rates and number of toll transactions are the most significant variables in the simple model. The interest rate on the reserve account also has a significant impact, followed by the cost of construction and the interest earned on the construction fund. The operating costs surprisingly did not rank as one of the top five contributors to the forecast values.

In response to the sensitivity analysis one may decide to expand the evaluation of the most sensitive variables. This enhanced risk model includes new representations of some of the original model variables plus the addition of new variables. These include modifying toll rate distribution, correlating costs and ridership, refining construction time and cost, and correlating inflation rates with toll levels and operating expenses.

Due to their importance, the toll rate distributions were adjusted to reflect more accurately the relationship between tolls and ridership. The traffic/toll study for this project indicates that revenues increase almost linearly where toll rates are increased to a moderate level. The distribution of the number of trips is coupled with the new distributions for the toll rates by using a negative correlation coefficient (–0.9) between the number of toll transactions (i.e., the number of trips) and the toll amount.

Another refinement of the model is the addition of a correlation to represent the increased costs associated with increased ridership. Increased costs are incurred with operating the toll booths when traffic is high. Additionally, the maintenance costs for the road will increase with higher traffic. A coefficient of 0.5 is used to represent this relationship.

In the enhanced model the impacts of variations in the construction schedule also were assessed more rigorously. The likelihood of attaining the schedule for each revenue generating portion of the toll road was evaluated independently. By separating the toll generating sections, individual delays in construction time and construction cost overruns can be incorporated accurately into the Monte Carlo model.

Finally, the impact of inflation rates was added to the enhanced model. Inflation rates throughout the life of the bond will have a significant effect on the ability to service the debt. Inflation may exceed expected rates, which in turn would affect the tolls charged for a given year. However, the required debt service remains constant for the fixed rate senior bonds. As a result, higher than expected inflation rates will have a positive effect on the project. The impacts of foreseeable variations in inflation rates can be included in the model by correlating the variable for inflation rates with changes in toll levels and operation expenses.

The revised Monte Carlo model yields a mean value for the year 2003 type I debt coverage of 1.29 which is slightly lower than the first model. However, even though the mean value of the type I debt coverage did not change substantially, the change in the standard deviation of the type I debt coverage was significant. As seen in Figure 4 the distribution of debt coverage is now slightly skewed to the right (maximum value = 1.7) but it also indicates the possibility (however slight) that debt coverage will be less than 1.0.

As previously explained, the enhanced model includes the impact of inflation on the debt coverage calculations. A sensitivity analysis for the enhanced model would show clearly that inflation rates have a far broader impact than any other variable in the project, due to the large number of items which are influenced by this value. To increase investors' comfort level with this toll road project, an extended study of likely inflation rates could be conducted.

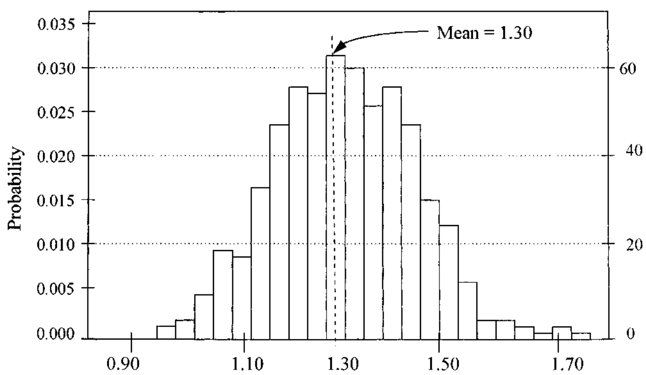

Figure 4 Frequency distribution – debt coverage (enhanced model) for the year 2003

Summary and conclusion

Current alternative procurement methods include privatization of revenue dependent infrastructure projects. Increased risk exposure associated with these new methods suggests development of enhanced decision making tools. This paper demonstrates a Monte Carlo risk assessment methodology which provides enhancements to traditional investment studies. These enhancements include probability distributions, correlations, sensitivity analysis, and external variables. Results provide project stakeholders graphic bestcase–worstcase analysis and problem refinement tools. The methodology provides a flexible decision making tool for assessing the feasibility of privatization projects. Improved assessment of project risks encourages appropriate risk modification, mitigation, and avoidance for highly uncertain investment projects such as toll roads.

Monte Carlo risk modelling is not without limitation. Although little can be done to alter significantly the underlying risk of a toll road project, appropriate identification of critical risks allows project participants to avoid, manage and or mitigate risks. However, effective model development must first identify project specific risks. Failure to identify significant risks quickly undermines model validity and therefore analysis results. Additionally, serious risks such as changes in law or government regulation while establishing boundary conditions on the overall decision process generally are so rare that they are not included in model development.

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