INFRISK

A computer simulation approach to risk management in infrastructure project finance transactions

Designed and developed by

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Managing Risk

Few issues in modern finance have inspired the interest of both practitioners and theoreticians more than the subject of risk evaluation and management.[1] "The ability to understand, measure, and weigh risk is," according to Peter Bernstein, "at the heart of modern life.[2]" Virtually every investment and financing decision involving intertemporal allocation of resources under uncertain conditions is associated with some risk, which is in effect, either assumed in the expectation of a higher return, or is transferred to others through hedging and/or contracting arrangements.

Yet, increased exposure to risk has been an inevitable consequence of recent economic, technological, and financial changes, which have come to represent the defining themes of the 1990s. These include the globalization of economic activity, the mobility of capital flows across national boundaries, widespread privatization of public sector enterprises, intensified competition, and high volatility in international financial and currency markets. In the face of such paradigmatic developments, the viability of long-term capital investments, particularly in the core infrastructure sectors of power, transport and telecommunications, hinges critically on how risks associated with such investments are evaluated and managed.

The basic principle governing risk management in an infrastructure project finance deal is intuitive and well articulated:[3] allocate project-specific risks to parties best able to bear them (taking into account each party's appetite for and aversion to risk), control performance risk through incentives, and use market hedging instruments (derivatives) for covering market-wide risks arising from fluctuations in, for instance, interest and exchange rates. In practice, however, difficulties arise due to market imperfections, i.e., derivative markets (swaps, forwards) for currency and interest rate risk hedging that are either non-existent or not sufficiently developed in most emerging countries, limited contracting possibilities (due to enforceability and credibility problems), and differing methodologies for risk measurement and evaluation. As a result, governments have been asked to provide guarantees for various kinds to projects, often at no charge.

Project Risk Evaluation

There are two important aspects of infrastructure project finance that distinguish it from corporate and traditional limited recourse project finance: (a) a high concentration of project risks in the early phase of project life cycle, i.e. the pre-completion phase; and

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[1] Not surprisingly, risk management has grown in recent years into a mature discipline with a wealth of literature, specialized skills, and sophisticated computer-basted systems that can be applied to investment project appraisal, pension plans, portfolio asset allocation, credit derivatives, regulatory capital adequacy for the banking sector, and derivative trading.

[2] See Bernstein (1996).

[3] The argument for risk management in project finance is stronger than in corporate finance. In the case of corporate finance, the argument for risk management or hedging rests on the notion that hedging adds value to the extent that it helps ensure that a company has sufficient internal funds available to take advantage of attractive investment opportunities. See Froot, Scharfstein, and Stein (1993). In a project finance deal, risk management bears directly on the success or failure of the project.

(b) a risk profile that undergoes important changes as the project comes to fruition, with a relatively stable stream of cash flows that is subject to market and regulatory risks once the project is completed. Figure 1 below describes the main risks that arise in the development and operational phases.

Figure 1: Project life cycle: main risks

Main Risks:

- Completion Risk
- Cost Overrun Risk
- Performance Risk
- Environmental Risk

Main Risks:

- Performance Risk
- Regulatory Risk
- Environmental Risk
- Off-take Risk (Power Projects)
- Market Risk (Toll Roads)

Risk Management Through Contracts

Project finance transactions are typically governed by a nexus of long-term formal contracts, written between the project promoter, the host country government, creditors, input suppliers, contractors, operators, and service providers (in the case of power). Three classes of contracts are important: concession agreements that stipulate a property rights transfer from the government to the project company, performance contracts between the project company and contractors and operators, and loan contracts between creditors and the project company. Such contracts are designed to share risk and to protect contracting parties against opportunistic “hold-up” behavior by others. In practice, they address two important characteristics of infrastructure investments: (i) a high degree of asset specificity; and (ii) large project-specific risks that cannot be diversified in financial markets.

In such “relationship-specific” investments, i.e. constructing a power plant, road, or bridge which cannot readily be removed and used elsewhere, investors are hesitant to make investments without adequate contractual protection. Once the investment is sunk, the incentive system and the bargaining power of contracting parties change vis-à-vis each other.[4] Anticipating such an outcome, project promoters often insist on governments providing various kinds of guarantees to cover, for instance, the credit risk of the power purchaser under an IPP arrangement, or a minimum level of revenue in a toll road project.

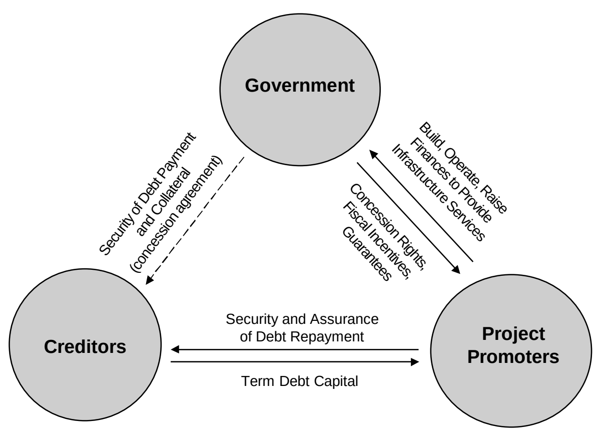
[4] See Dailami and Klein (1999) for a further discussion of the contracting forms in infrastructure finance transactions and for a review of the related literature.

***INFRISK*: A Tool for Risk Management**

This study introduces *INFRISK*, a computer based risk management approach to infrastructure project finance transactions that involve the private sector. Increasing the participation of the private sector in the provision and financing of infrastructure services is a common policy objective in countries around the world. As governments are turning to private firms as owners, operators, and financiers of infrastructure, the traditional financing structures and risk allocation strategies (once based on the sovereign's ability to tax and borrow) are now giving way to a reliance on fee-based project financing where risk management takes on a far greater importance.

INFRISK, developed in-house within the Economic Development Institute of the World Bank, is intended as a guide to practitioners in the field and as a training tool for raising awareness and expertise in the application of modern risk management techniques. It is capable of analyzing a project's exposures to a variety of market, credit, and performance risks from the perspective of key contracting parties in an infrastructure transaction, i.e. the project promoter, creditor, and the government. An infrastructure project is brought to financial closure, i.e. a transaction takes place, when these parties strike a balance, reaching a common ground of interest and understanding.

Figure 2: Major Parties to an Infrastructure Project: Analytical Framework



It is useful to think of this common ground as the solution to a bargaining game within which each party maximizes its objectives, subject to the constraints set by the willingness of others to participate. Modeling such a sequential multi-party bargaining game is difficult, as most game theoretic approaches rely heavily on the idea of "utility," which is difficult to apply operationally.[5] The perspective that drives the *INFRISK* "analytic" is the concept of the *economic viability* of a project (see Box 1).

[5] While the objectives of the creditor and project promoter can be reasonably specified as the security of loaned funds and the optimization of investment value, respectively, the government presents difficulties. Even a simplistic fiscalist approach to governments' behavior requires the estimation of social welfare losses from discriminatory taxation and the social cost-benefit calculus of the public finance alternative.

Box 1: Economic Viability of a Project

The economic viability of a project is an important concept in the process of project selection, and can be analyzed at two levels. The first level takes into account the particular regulatory structure in place for the project, including the determination of a tariff and the type of government support (guarantees, fiscal incentives, and credit enhancement). Here, viability boils down to whether cash flows are sufficient to service the project's debt on time, and to pay a fair return to its equity holders. At a deeper level of analysis, however, economic viability also depends heavily on the consistency of the tariff rate, the government's credibility in honoring a contracted rate level, and the project's cash flow stream. Project viability therefore hinges on the government's tariff policy and support for the project, since cash flows in monopolistic markets depend importantly on the tariff charged.

We analyze project viability from the perspective of creditors and equity holders in the project. From the viewpoint of **equity holders**, we focus on the main project metrics such as IRR and NPV. A project's *IRR* is a function of the tariff charged on the supply of infrastructure services, government support, and the financing mix and terms; more specifically, we assume:

$$IRR = f(m,r,l,s,p)$$

Where m is debt maturity, r is interest rate, l is a measure of the project's debt-equity ratio, p is the tariff charged, and s represents a vector of government support, i.e. tax incentives, depreciation allowances, and guarantees provided to the project. In general IRR is an increasing function of m, l, s and p, but a decreasing function of r.

From the **creditor**'s perspective, we focus on the project's capacity to borrow. We define loan payment capacity in terms of two main leverage ratios: i.e. interest coverage and debt service coverage. From a lender's point of view, the key criteria are the probability that such coverages are not less than some target levels, thus defining the following probabilities:

$$\text{Prob[Interest coverage} < \alpha_1] = \varepsilon_1$$
$$\text{Prob[Debt service coverage} < \alpha_2] = \varepsilon_2$$

Where α_1 and α_2 are leverage coverage ratios, and ε_1 and ε_2 are the respective confidence levels with which the lender feels comfortable.

$$\text{Interest coverage} = \frac{\text{Earnings Before Interest and Taxes}}{\text{Interest Payment}}$$

$$\text{Debt Service Coverage} = \frac{\text{Earnings Before Interest, Tax and Depreciation}}{\text{Interest} + \dfrac{\text{Principal Repayment}}{\text{1 - Tax Rate}}}$$

The **government**'s willingness to participate is given by a social welfare function, *W*, defined as:

$$W = \begin{cases} lI - (1+l)(t)\text{ , } if \text{ the investment is made} \\ 0\text{ , } if \text{ there is no investment} \end{cases}$$

where $0 \leq l < 1$ is a measure of welfare-loss from distortionary taxation, I is the project's investment size, and t is the present value of the net transfer of resources from the government to the private sector.

Project evaluation under uncertainty

INFRISK draws on recent developments in the literature on project evaluation under uncertainty[6] to generate *probability distributions* for key decision variables, such as a project's net present value (NPV), internal rate of return (IRR), or a project's capacity to service its debt on time during the life of the project. Such distributions are then used in assessing a project's economic viability, which is taken as the key criterion in project selection. Thus, judgement on the economic viability of a project is not based solely on a single "best estimate" of a project's metrics, i.e. net present value or debt service capacity, but also on the possible ranges of such variables and the likelihood of their occurrence within given ranges (see Box 1).

INFRISK is capable of handling several sources of uncertainty and risk bearing on a project's economic viability. Such risks, for example, could be associated with the *revenue stream* (tariff rate, demand forecast for electricity in a power project, or traffic volume forecast in a toll road project), *operations and maintenance costs,* and *construction cost.* The user has the option of choosing the key risk variable or variables upon which to focus, depending on the specific features of the infrastructure project at hand and the questions being addressed.

For a particular risk variable of interest, the program first generates a stream of probability distributions for each year of a project's life through a Monte Carlo simulation technique, the methodology for which is well known and is described in Box 2 and Annex 1. Typically, the relevant risk variable in a project, i.e. demand forecast, costs, and tariffs can be quantified in terms of both single best-guess estimates as well as a range of estimates over the life of a project or the early years in a project's life. Using such information, a suitable probability distribution is assigned to each risk variable within a specified range. Care must be taken to ensure that such *a priori* assigned probability distributions are consistent with the economic/statistical time series characteristics of relevant risk variables. For instance, exchange rates are known to obey a log-normal distribution, while revenue from a toll-road project is likely to exhibit an asymmetric probability distribution profile, such as a Beta distribution. *INFRISK* offers the flexibility of incorporating four classes of probability distributions (uniform, normal, lognormal, and beta) which provide a broad menu of probabilistic representation of relevant economic variables in an infrastructure project.

Specification of uncertainty through time may affect a project's cash flows and is also an important issue in project valuation. The pattern according to which uncertainty is resolved over time clearly varies from project to project, and requires careful consideration. For most infrastructure projects, the nature of risk changes fundamentally as the project reaches completion and is ready for operation. For this reason, *INFRISK* explicitly recognizes the two main phases of project development and project operation. To specify how risk evolves over time, we focus on the variance of a given risk variable.

[6] The literature on project appraisal under uncertainty goes back to Hertz (1964, 1979) and work done at The World Bank in the early 1970s (Pouliquen, 1970, World Bank, 1970). Subsequent contributions include Hertz and Thomas (1983), and most recently, the application of real option-theoretic models to project valuation. See also Paddock, Siegel and Smith (1988); as well as Copeland and Keenan (1998).

As shown in Box 2, information on the evolution of variance can be obtained from the time series' characteristics of the variable, or from the estimated range.[7]

Computationally, *INFRISK* works in conjunction with Microsoft Excel and supports both the construction and the operation phases of a capital investment project. The input to the simulation exercise includes data on projected revenues, operating costs, and other risk variable inputs which are part of the standard forecasting and cash flow analysis.

INFRISK Analytics

At the heart of *INFRISK* is a generic financial model, describing the year to year uses and sources of funds in the context of the project's initial capitalization, its income-expenditure flows, cash flows, as well as certain specific accounts established for servicing of debt (debt service reserve), operations and maintenance, tax payments, and general accounts (see Table 3 in the Annex). The drawdown of funds during the construction period and the distribution of cash flows during the operation phase are governed by a hierarchy of claims embedded in the contracts and loan covenants. If a project, for instance, takes three years to be constructed and the distribution of total capital expenditures is given by 25% (1st year), 50% (2nd year), and 25% (3rd year), it is assumed that equity funds are also drawn according to the same pattern. *INFRISK*, however, has the flexibility of incorporating a different pattern of capital expenditure disbursement, as well as equity drawdown, depending on the particular project at hand.

Driving the financial model are project specific sub-models determining operating revenues and costs, as functions of tariffs, capacity, output, and input prices and quantities. In a power project, for instance, operating revenues could consist of payments for electric generating capacity and energy, and associated steam (in a cogenerated plant), as provided under the Power Purchase Agreement, and operating costs dependent on fuel usage and prices as well as the operation and maintenance expenses.

Currently, *INFRISK* operates on an annual, year-by-year basis. Work, however, is underway to introduce calendar time (day, month, year) as the basis for analysis in line with the actual functioning of financial markets and contracts.

Box 2: Probabilistic-based simulation

Technically, the stochastic process $\{ Y_t \mid t=1,\ldots,T \}$ can represent the possible realization of a risk variable, Y, in an infrastructure project, over the project's lifetime, where T is the life of the project, i.e. concession period. It is useful to represent the value of Y in year t (Y_t) as the sum of its projected value, m_t, and a random variable, u_t, as follows:

$$Y_t = m_t + u_t \tag{1}$$

$$u_t = a_t^{1/2} e_t \tag{2}$$

[7] In much of the finance literature, risk is modeled to evolve monotonically with time, through the dominant application of diffusion process of Brownian motion, where variance increases through time.

where { ε_t } is an independently distributed random sequence, with a mean of zero and unit variance, that is, $E(\varepsilon_t) = 0$, var (ε_t) = 1, $E(\varepsilon_t, \varepsilon_s) = 0$, and $t \neq s$.

From equations (1) and (2), it is easy to see that $E(Y_t) = m_t$, and var (Y_t) = a_t as ($t = 1,\ldots,T$). Thus in generating the probability distribution functions { $F_t(\bullet) \mid t = 1,\ldots,T$ } for { Y_t }, it is necessary to specify m_t, a_t as well as the specific distribution form of e_t.

In principle, m_t can be estimated from information contained in a project description. In the case that { $Y_t \mid t=1,\ldots,T$ } represents a project's operating revenues, for instance, it is possible to write $m_t = m(X_t, b)$ where X_t is a vector of exogenous variables indicating relevant demand and technical factors and b is a corresponding vector of fixed parameters. In this case m_t can be interpreted as the projected or forecasted operating revenues over a project's lifetime, which is generated from assumptions on the tariff structure, demand forecast, and any indexation or escalation factor involved.

Computationally, the Monte Carlo simulation technique used in *INFRISK* is based on N randomly sampled iterations (N = 1000) for a risk variable{ $Y_t \mid t=1,\ldots,T$ }. The i^{th} iteration is given by:

$$Y_t^i = m_t^i + \sqrt{a_t}\; e_t^i \tag{3}$$

for each year in the life of the project. Thus, focusing on the first year of the project's operation, we have:

$$Y_1^i = m_1^i + \sqrt{a_1}\; e_1^i \tag{4}$$

One representation of (4) is the Martingale process, suggested by Hurley (1998), which is given by:

$$Y_t = Y_{t-1} + u_t \tag{5}$$

$$u_t = \sqrt{a_t}\, e_t \tag{6}$$

letting $\alpha_t = \delta^2 \gamma^{t-1}$. Then we have $E(Y_t) = \hat{Y}$, $t = 1,\ldots,T$ and

$$\text{var}(Y_t) = \left(\frac{1-g^t}{1-g}\right) d^2, t = 1,\ldots,T \tag{7}$$

In most cases analysts have reliable information not only about the projected m_t, but also a range *range*(Y_t)= maxY_t - min Y_t } within which m_t can be assumed to lie. Using the information on the projected range of a risk variable, it is possible to estimate d Thus, for the *normal distribution*, we estimate the standard deviation in the first year as:

$$d = \frac{range(Y_1)}{d} \tag{8}$$

where the constant d can be taken as 6, given that for the normal distribution most of the data (approximately 99.7%) falls in the interval of 6 standard deviations around the mean. For the *uniform distribution*, $e_1 \sim U(-0.5\,\text{range}(Y_1), 0.5\,\text{range}(Y_1))$, and

$$d = \frac{range(Y_1)}{\sqrt{12}}. \tag{9}$$

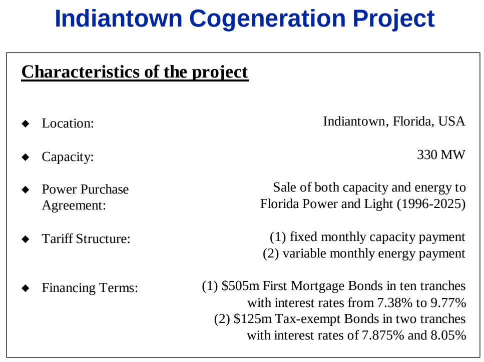
For the transformed *beta distribution*, $u_1 \sim \text{range}(Y_1)\,beta(a, b) + A$, ($A$ is the mean preserving constant), $A = \hat{Y}_1 - range(Y_t)a/(a+b)$, and

$$d = range(Y_1)\sqrt{\frac{ab}{(a+b+1)}\frac{1}{a+b}} \approx 0.16(range_1) \tag{10}$$

when a=2, b =5, for instance.

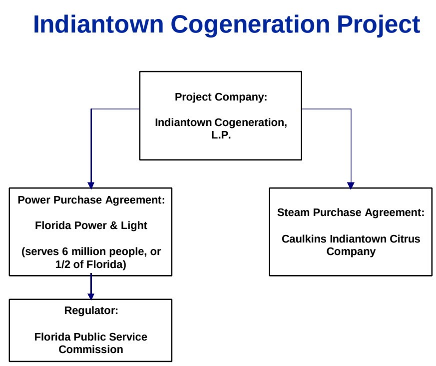
Model of an IPP – The Indiantown Cogeneration Project

To illustrate the application of *INFRISK* to a real-life project, we draw on the Indiantown Cogeneration Project in this section. This project provides an excellent test case due to the extensive amount of detailed public information that is available on the project's financing mix, regulatory environment, and projected operating results which are contained in the prospectus for the 1994 bond issues. This information is readily obtainable through the U.S. Securities and Exchange Commission and the project company. A detailed examination of the Indiantown project is also available from Finnerty (1996).



The Indiantown Cogeneration Project is a coal-fired facility with an electric generating capacity of 330 megawatts (MW) and a steam export capability of 175,000 pounds per hour. Construction of the facility, located in Martin County, Florida, began on October 21, 1992 and was completed in 1996. Construction of the project was financed with a $140 million equity contribution from the partners, $505 million in First Mortgage Bonds (1994), and $125 million in tax-exempt bonds (1994) arranged through the Martin County Industrial Development Authority.

The project company entered into a 30-year Power Purchase Agreement (PPA) with the Florida Power & Light Company (FPL), a utility under the regulatory authority of the Florida Public Service Commission. FPL's service area covers 35 counties in Florida with a population of 6 million or approximately half the population of Florida. The PPA features a two-tiered pricing arrangement consisting of: (i) a fixed capacity charge covering fixed operational costs, and other financial commitments; and (ii) a variable energy charge covering costs of fuel and variable operations and maintenance expenses. Additionally, the project company contracted to provide its cogenerated steam to the Caulkins Indiantown Citrus Company for a period of 15 years.



The following section presents a simplified financial model of such an IPP. The purpose is to highlight the implications for project viability of the credit risk of the utility off-taker. The model focuses on features such as pricing and long-term contracting, which are common in IPPs.[8]

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[8] See Dailami (1999) for a more detailed discussion.

The basic equations determining contracted revenues, expenses, and escalation factors can be summarized as:

Basic equations:

Electric operating revenue:

$$R_t = 8760\left[lM(p^c + p_t^f)\right] + p_t^e Q_t \tag{1}$$

Electric output:

$$Q_t = \tilde{d}_t M \tag{2}$$

Operating costs:

$$E_t = f(M)P_t^f + OM_t \tag{3}$$

Operating income:

$$I_t = R_t - E_t \tag{4}$$

Escalation factors:

$$p_t^f = p_1^f (1 + g_1)^{t-1} \tag{6}$$

$$p_t^e = p_1^e (1 + g_2)^{t-1} \tag{7}$$

$$P_t^f = P_1^f (1 + g_f)^{t-1} \tag{8}$$

where:

R_t	=	contracted electricity revenue in year *t* (million US$)
M	=	installed capacity (MW)
l	=	capacity payment multiplier
p^c	=	capacity rate ($/KWh)
p^f	=	fixed capacity rate for operational costs ($/KWh)
p^e	=	variable unit energy price ($/KWh)
OM_t	=	operations and maintenance expenses
Q	=	energy produced (KWh x 10^3)
g_1	=	rate of inflation in the GDP price deflator
g_2	=	projected rate of inflation in the fuel price

In discussing revenue risk, we first distinguish between a contracted level of revenue R_t and the actual level of revenue $\tilde{R}_t$. The actual level of revenue will be a random variable depending on the level of actual demand and whether the utility actually pays as agreed.

To incorporate the credit risk of utility off-takers, we have:

$$\tilde{R}_t = \min(R_t, \tilde{Z}_t) \tag{9}$$

where $\tilde{Z}_t$ is a random variable reflecting the capacity payment of the off-taker.

We assume that the payment capacity of the utility off-taker can be characterized by a normal probability distribution with a mean equal to its promised or contracted payment to the IPP, i.e. R, and a standard deviation of q%. Thus:

$$Z \sim N(R, q^2 R^2) \tag{10}$$

Note that q measures the degree of riskiness of the utility off-taker. The higher the value of q, the higher the riskiness or the lower the creditworthiness of the off-taker.

Figures 3, 4, and 5 show respectively, the simulated probability distributions for the Indiantown Power project's net present value, dividend payment, and debt service ratio in the year 2005.[9]

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[9] Alternatively, the payment capacity of power purchaser can be characterized by two distributions:

(i) a discrete distribution describing that the power purchaser is not able to serve its contractual value R_t on time and in full. Let this probability be P_t in year t.

(ii) given that the power purchaser is in default, let the proportion of contracted value that can be recovered in year t be denoted by a random variable y_t, with support ($0 \le y_t \le 1$), and with the conditional probability distribution $f_t(\bullet)$, which can be assumed to obey a beta distribution. In this case, $\tilde{R}$ will be determined by the joint distribution of p and y, i.e. $\tilde{R} = g(p, y)$ with the expected value given by $E(\tilde{R}_t) = R_t(1 - P_t) + P_t R_t \int_0^1 y f_t(y) dy$. See Dailami (1999) for details on this approach.

Figure 3: Probability Distribution of Net Present Value

Risk factor: Total Revenue

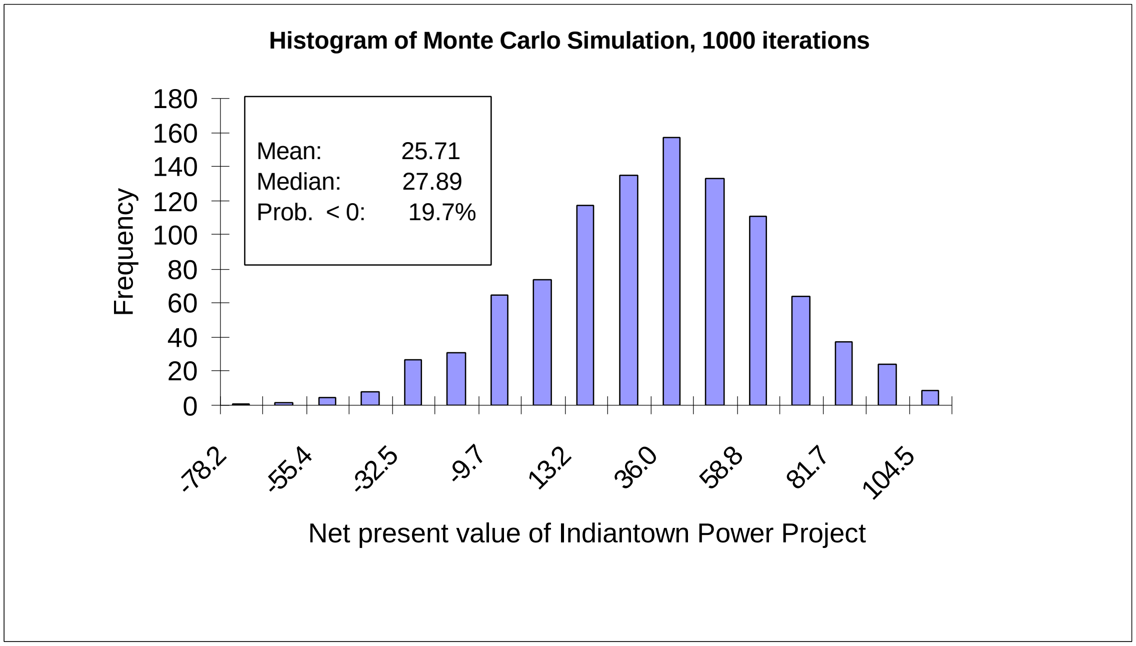


Figure 4: Probability Distribution of Dividend in Year 2005

Risk factor: Total Revenue

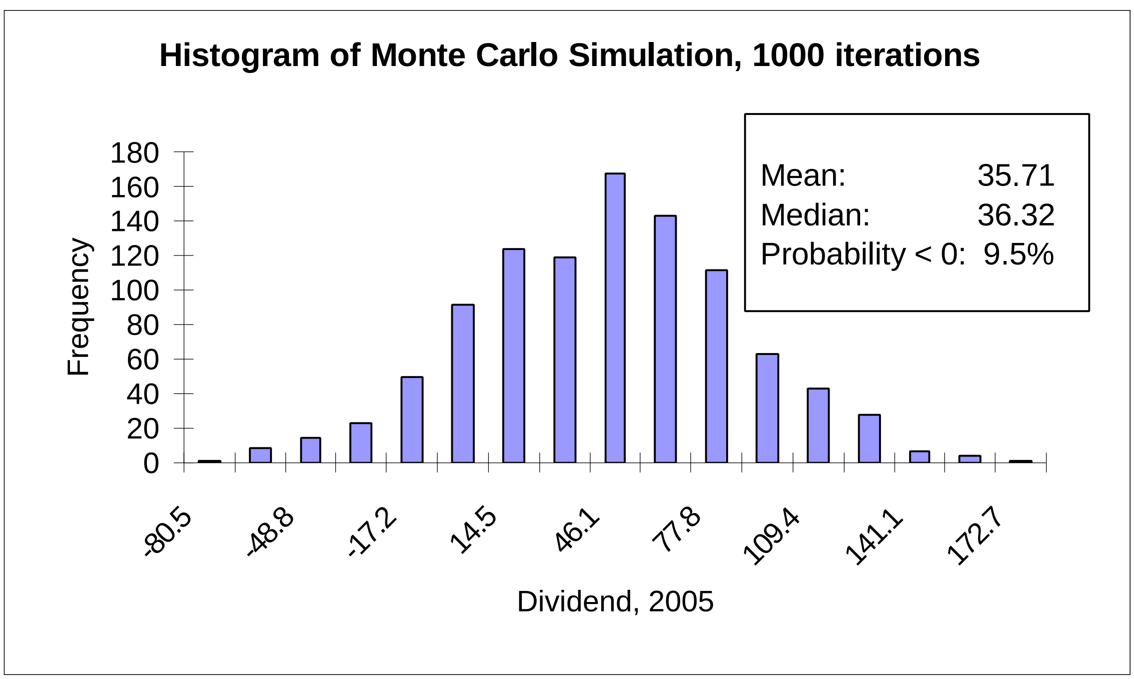


Figure 5: Probability Distribution of Debt Service in Year 2005

Risk factor: Total Revenue

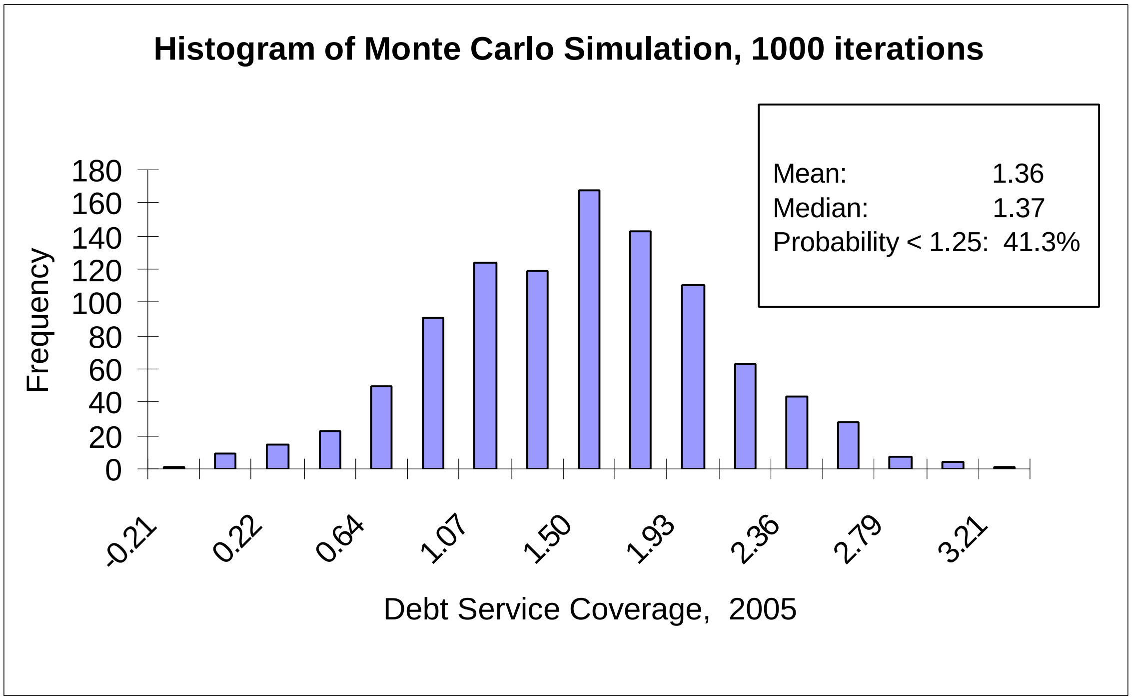
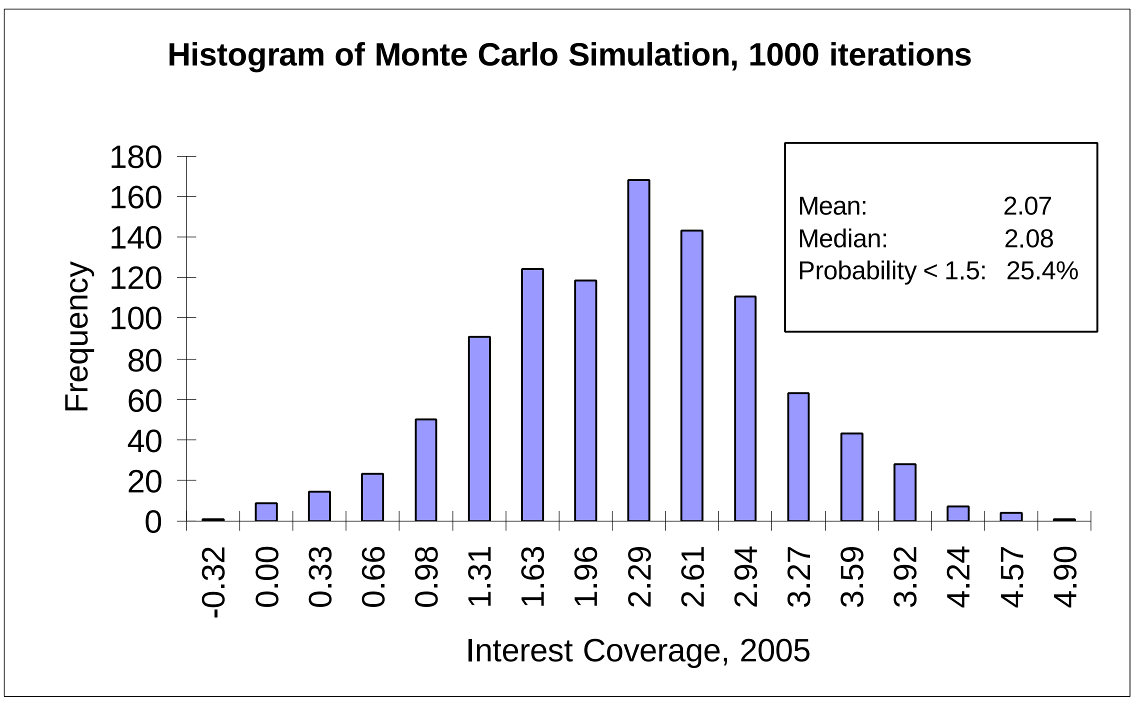


Figure 6: Probability Distribution of Interest Service in Year 2005

Risk factor: Total Revenue



INFRISK

User Guide
Summary Version

This user guide is divided into three main sections:

I. Inputting project data into INFRISK

II. Using the dialog boxes to specify desired settings for the simulation

III. Customizing and understanding the simulation output

I. Inputting Project Data into *INFRISK*

In *INFRISK*, the project data for the simulation is inputted both through an input sheet and the *INFRISK* dialog boxes. The input sheet contains fundamental project data for each year of the project. The data on this sheet is divided into two sections: one for the construction period and one for the operational period.

The program offers a large degree of flexibility when the user is creating her own input sheet. Different types of inputs can be placed anywhere within the appropriate section (construction or operation) and in the order of the user's choice. However, the two sections must be separated, and each of them starts with the *heading line* that labels the subsequent columns with the year identifiers (i.e., 1992, 1993, etc.). For the *Construction Phase* table, the heading line must contain *YRCON* in the second column (as shown on the example sheet below). Correspondingly, for the *Operation Phase* table, the heading line must contain *YROPER* in the second column. To identify the data, the user must include the appropriate label (for example, "OR" for operating revenues) in the second column as in the example below. The label in the first column is for descriptive purposes only and may be customized as desired by the user. Annex 1 provides a typology of flow and stock variables familiar to *INFRISK*.

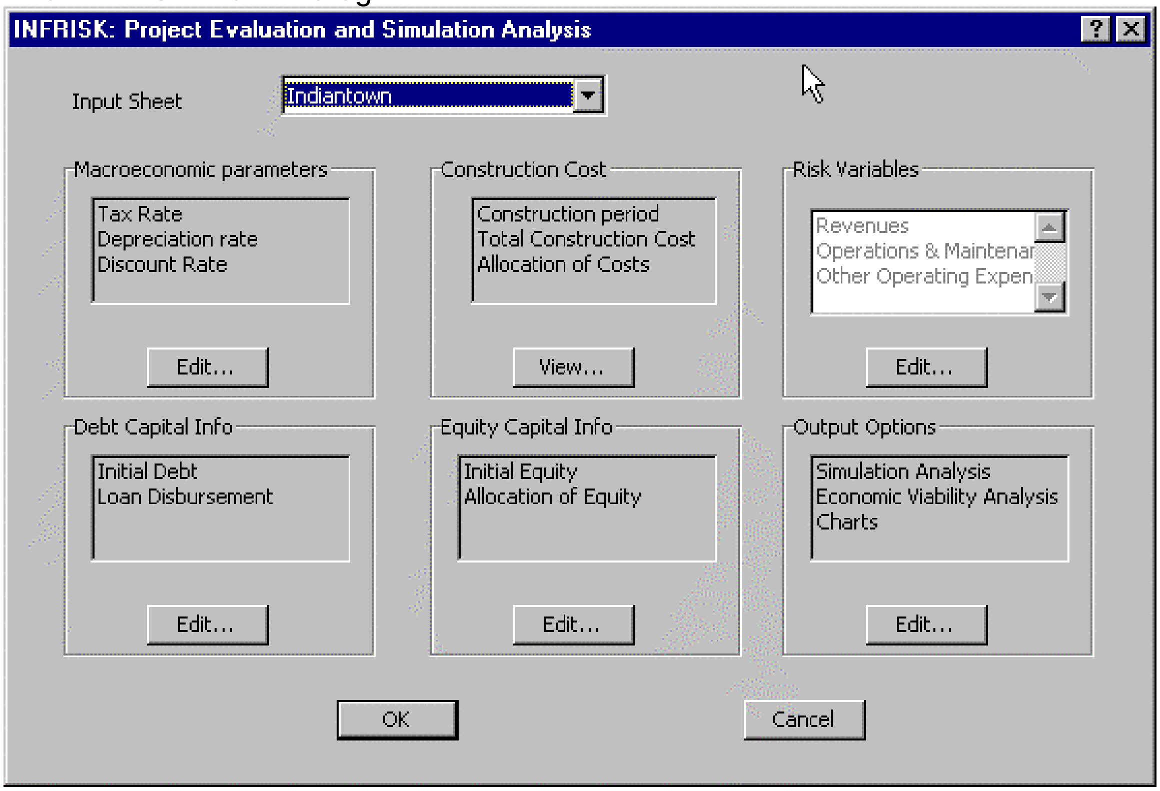
Figure 7: *INFRISK* Input Sheet

	Label	***UNITS***								
Construction Phase	*YRCON*		***1992***	***1993***	***1994***	***1995***				
Financing Costs during Construction	IK	USD	0		90.865	90.865				
Capital Construction Costs	CK	USD	109.6825	109.6825	109.6825	109.6825				
Range of changes for CK due to random fluctuations	CKRange	USD	21.9365	21.9365	21.9365	21.9365				
	DBA-12	USD	0	12	0	0				
	DBA-11	USD	0	113	0	0				
Other capital expenditures	OK	USD		49.849	49.849	49.849				
Equity	ES	USD	109.68	30.32	0	0				
Ending Exch Rate	Et	USD	1	1	1	1				
	DBA-1	USD	0	4.21	0.187	0				
	DBA-2	USD	0	0	4.398	0				
	DBA-3	USD	0	0	4.85	0				
	DBA-4	USD	0	0	4.851	0				
	DBA-5	USD	0	0	5.132	0				
	DBA-6	USD	0	0	5.133	0				
	DBA-7	USD	0	0	4.998	0				
	DBA-8	USD	0	0	4.999	0				
	DBA-9	USD	0	0	197.839	0				
	DBA-10	USD	0	0	18.01	250.392				
Operation Phase	*YROPER*		***1996***	***1997***	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***
Fixed Capacity Payment		USD	116.412	123.575	124.212	124.937	125.709	126.531	127.406	128.337
Variable Revenue		USD	49.404	61.844	63.834	66.094	68.575	64.931	73.974	76.819
			165.816	185.419	188.046	191.031	194.284	191.462	201.38	205.156
Non-random part of revenues	*NR*	USD	***116.41***	***123.58***	***124.21***	***124.94***	***125.71***	***126.53***	***127.41***	***128.34***
Random part of Operating Revenues	OR	USD	49.404	61.844	63.834	66.094	68.575	64.931	73.974	76.819
Range for the Operating Revenues	ORRange	USD	24.702	30.922	31.917	33.047	34.2875	32.4655	36.987	38.4095
Other Expenses		USD	14.589	15.605	16.007	17.795	16.757	20.025	21.303	18.61

The program also permits the user to switch easily between different sets of projections for a project. This is done on the main dialog (shown on the next page) by selecting the name of the sheet containing the desired data in the combo box labeled "input sheet."

II. Using the dialog boxes to specify desired settings for the simulation

The *INFRISK* Main Dialog



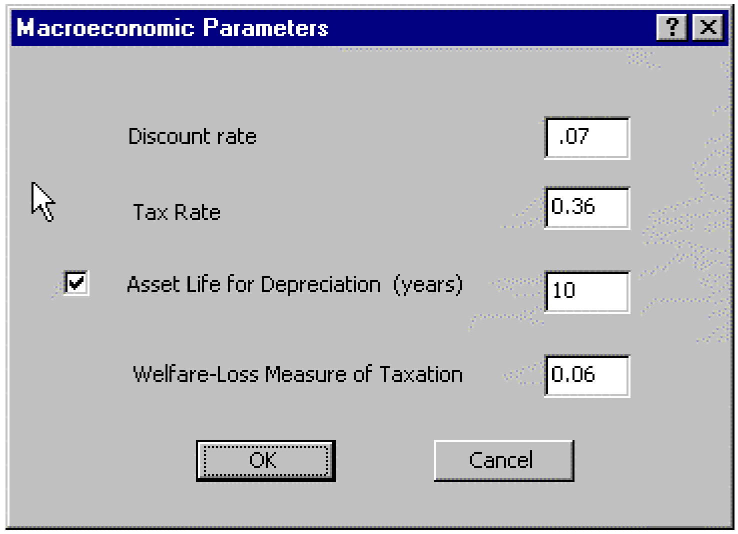
Once the main project data are entered in the input sheet, the user can specify the settings regulating the functioning of the *INFRISK* simulation. This is done through the main dialog's key sections, which cover the following areas:

- Macroeconomic Parameters
- Construction Cost (*Note:* Information on construction costs can be viewed but not changed in the dialog box. It can only be changed on the input sheet.)
- Risk Variables
- Debt Capital Info
- Equity Capital Info
- Output Options

Clicking the 

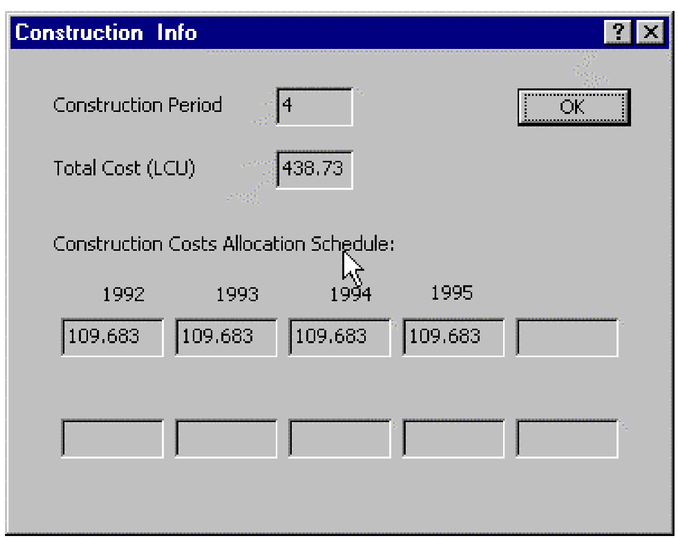
button in any of these sections allows the user to modify the simulation settings. For example, to set the *tax rate*, click the edit button in the macroeconomic parameters section, which will open a dialog where the tax rate can be changed. The following pages give a more detailed breakdown of the capabilities of each of the sections of the main dialog box.

Macroeconomic Parameters



In this dialog, the user can specify the main macroeconomic parameters that have direct influence on a project's cash flows, such as the applicable discount rate, the corporate income tax rate, allowable asset life for calculating depreciation for tax purposes, and a measure of welfare-loss due to distortionary taxation (used in the INFRISK social welfare function to calculate the government's willingness to participate in a project.)

Construction Cost

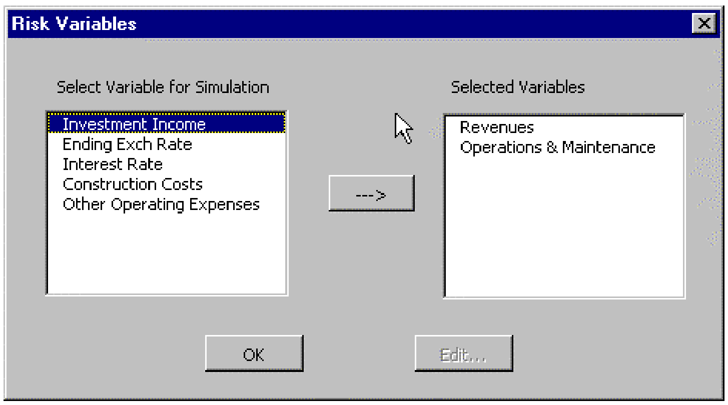


This dialog is for informational purposes only and allows the user to view information on the construction period, total construction cost, and the allocation schedule of costs over the construction period. Changing this data can be done through the specified input sheet via the variable labeled as *CK*.

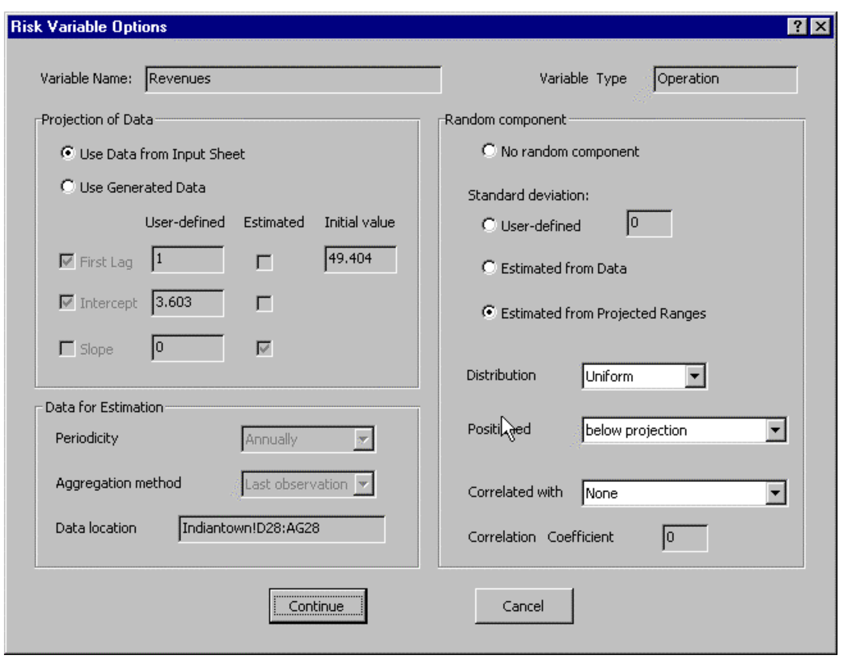
Risk Variables

INFRISK is capable of handling several sources of uncertainty and risk that influence a project's economic viability. Such risks, for example, could be associated with *revenue stream* (tariff rate or traffic volume forecast in a toll road project), *operations and maintenance costs,* and *projected construction cost* (in an IPP). The user has the option of choosing the key "risk variable" upon which to focus, depending on the specific features of the infrastructure project at hand.

For a particular risk variable, the program generates a number of probability distributions for each year of the project's life (concession) using a Monte Carlo simulation technique. *INFRISK* can use one of four probability distributions (uniform, normal, beta, and log-normal) as the error generator. Uncertainty through time is incorporated by specifying how the parameter (i.e. mean and variance) changes over time (see Annex for details).



Once a variable is selected for the Monte Carlo simulation, the Risk Variable Options dialog opens, allowing the user to specify the desired options. The projection of the data section of this dialog determines the source of data for the variable – it is either stored in the input sheet specified in the main dialog, or can be generated according to the user's specifications (by specifying lag, intercept, and slope). By manipulating these



three parameters, the user can specify a variety of models. For instance, the random walk process for the logs of exchange rate can be easily specified by putting a unit coefficient for the lagged value and zeros for all other. If the user does not know the values for some parameters, he can check the *estimated* option, then *INFRISK* will use the data specified at the *data for estimation* textbox to obtain its own estimate.

The *Random Component* section allows the user to specify the distribution function, and other parameters associated with it. If the data are expected to possess a stochastic term, the user can provide the parameters for the error term, namely its distribution and the standard deviation. Several options can be used to specify the standard deviations for the random process:

- User-defined standard deviation
- Estimated from the historical data (the location to historical data is specified in the *data for estimation* text box) using their residuals from the trend or deviations from a random walk model (first differences), when the projected values are used as the mean.
- Estimated from the ranges provided by the user in the input sheet. The ranges must be labeled following the format <VarLabel>Range (for instance, “ORRange”).

In this section, the user can also specify the following:

- *Distribution.* Allows the user to select the probability distribution function for the error term. Presently, *INFRISK* can handle four different error distributions: Normal, Lognormal, Beta, and Uniform. The “Beta distribution” option allows the user to model the errors around the trend using a right-skewed distribution based upon a member from the *beta* family (as an example, see Box 4 for a formal description of *Beta* distribution, its probability density function, and some important parameters).

- *Positioning.* Specifies whether the selected distribution is positioned around, above, or below the trend. Also the user can *truncate* all generated values above or below the mean value of the given distribution.

- *Correlated With* option allows the user to impose a certain correlation between pairs of random variables. For instance, in our example, the random component of *Revenues* can be correlated with the random component of the *Maintenance costs* (for a toll road project, it is safe to assume that toll road revenues are positively correlated with maintenance costs). The value of the correlation coefficient can be any number from –1 to 1 and is specified in the *correlation coefficient* edit box.

Box 4

The beta probability distribution function is given by the following expression:

$$f(x, \alpha, \beta) = k(\alpha,\beta)*x^{\alpha-1}(1-x)^{\beta-1}, \ 0< x <1, \alpha, \beta > 0,$$

Where the coefficient $k(\alpha,\beta) = \Gamma(\alpha+\beta)/\Gamma(\alpha)/\Gamma(\beta)$ does not depend on x. It can be easily shown that:

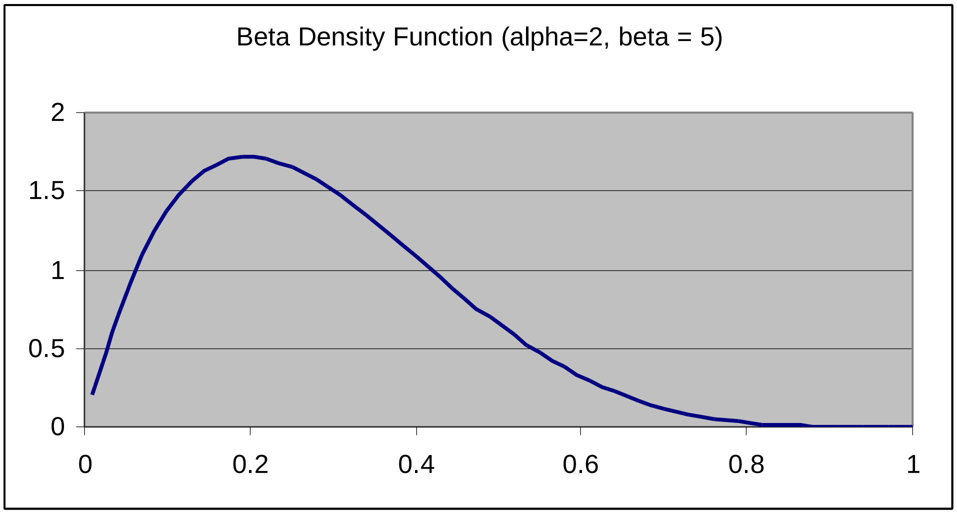
$$\mu = E(X) = \alpha/(\alpha+\beta)$$
$$\sigma^2 = Var(X) = \alpha\beta/(\alpha+\beta+1)/(\alpha+\beta)^2$$
$$m = Mode(X) = (\alpha-1)/(\alpha+\beta-2)$$

Table 1 contains the values of some important parameters of beta distribution for the case of $\alpha=2, \beta=5$

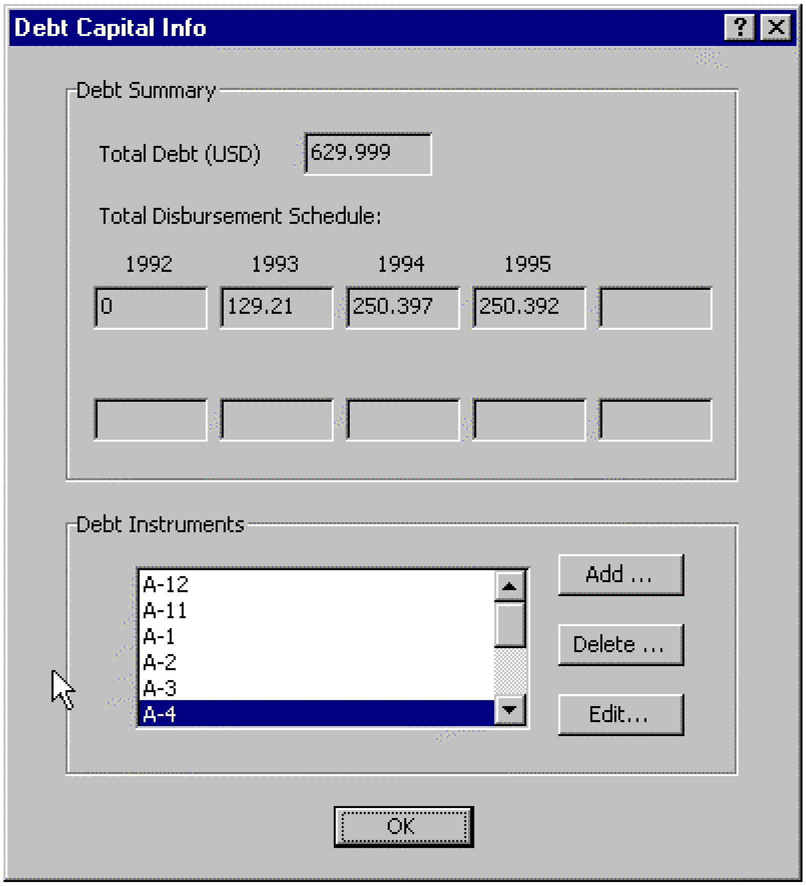
Table 1

mode	0.2
α	2
β	5
μ	0.286
σ	0.160
Prob($x<\mu$)	0.548
Prob(x<mode)	0.345

Figure 8: Beta Density Function

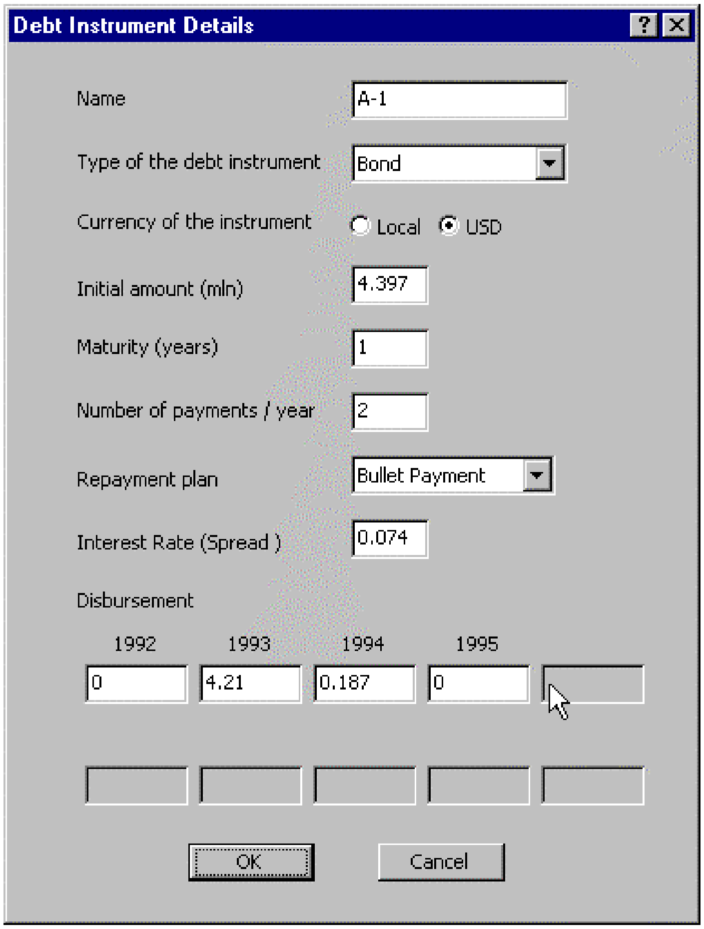


Debt Capital Info



The Debt Capital Info dialog has two components: "Debt Summary" and "Debt Instruments." The "Debt Summary" serves two functions: (i) it shows the total amount of debt capital used in the project, and (ii) it sets a plan for the disbursement of loan capital over the construction phase of the project. The data displayed in the debt summary component cannot be edited and is there only for information purposes. To avoid confusion, it is only changed in the input sheet. The "Debt Instruments" section provides a menu for specifying various sources of debt capital, and their terms. By pressing Add ... the user can insert a new debt instrument in the list. The Edit... button allows the user to modify the information for an existing debt instrument. When either of these buttons is pressed, the user is presented with a dialog where the characteristics of the instrument can be entered. This dialog is shown on the next page.

Entering Detailed Debt Instrument Information



The Debt Instrument Dialog Box contains the following options:

- *Name.* Allows the user to associate a name with any debt.
    - *Type of debt instrument.* Permits selection of Loan, Bond, or Letter of Credit.
    - *Currency of the debt instrument.* Note that local currency is defined as the currency in which the operating revenues are received
    - *Initial Amount.*
    - *Maturity.*
    - *Number of Payments/Year.*
    - *Interest Rate.* Enter in decimal form. In the case of an interest rate that is defined as a spread over a benchmark such as LIBOR, enter the projected values for the benchmark in the input sheet under the variable labeled *Ir*. Then enter the spread in decimal form in the interest rate box, e.g. a spread of 120 bps over LIBOR would be entered in this box as 0.012.

- *Repayment Plan.* May be specified as Equal Payments, Bullet Payment, or Defined Schedule. The Defined Schedule option allows the user to specify her own amortization schedule in the input sheet. The corresponding sheet variable must be labeled according to the format: SAM<loan name>. For instance, if the name of a given debt instrument is Loan1, the label will be SAMLoan1.
- *Disbursement Plan over Construction Period.* Provides edit boxes that allow the user to specify how the disbursement of the debt is distributed over the construction period. This information is also stored in the input sheet under the variables labeled as DBA<debtname>. For instance, if the name of a given debt instrument is Loan2, the label will be DBALoan2.

Box 5: Debt Parameters

INFRISK is capable of handling a wide menu of debt instruments, i.e. loans, bonds, and LCs. This representation is sufficiently general to encompass the main characteristics in the payment of both a loan and a bond issue. As an illustration, consider a debt with the face value \$D contracted at time 0, and to mature at time m, where $m \leq T$, when T is the length of concession. Associated with this debt is a stream of contractual payments, i.e., amortization, interest, and commitment fees, depending on the nature of the debt instrument, and characteristics. Thus, for a given time (τ),

$$DS(\tau) = AM(\tau) + R(\tau) + COM(\tau),$$

where DS = debt service payment, AM = amortization, *R* = interest, and COM = commitment fees, and

$$D = \sum_{t=0}^{m} AM(t)$$

In the case of a bond with fixed coupons and bullet payments at the maturity dates we have:

$$AM(t) = 0, \forall t = 1, m-1, \text{ and } AM(m) = D, \text{ and } R(t) = D ´ c,$$

where *c* is the fixed coupon rate. *In the case of a loan,* interest is paid on disbursed and outstanding amounts, and the commitment is charged on the amount committed, but not yet disbursed. Amortization is often agreed in advance, including grace periods. In a loan with periodic equal payments, the payment is defined as follows:

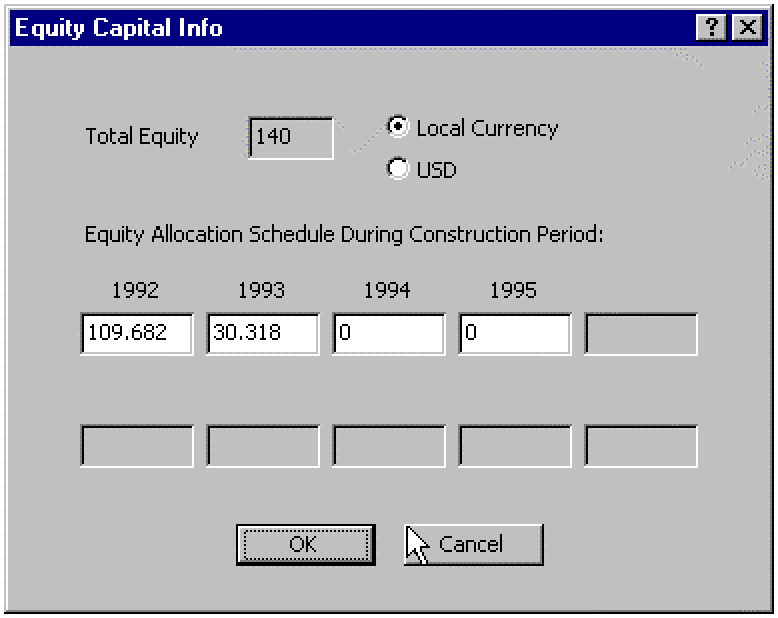
$$PMT = L\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right]$$

L = Initial loan
PMT = end of period payment (equal payments)
i = interest rate
N = number of end of period payments

The amortization part of the payment is as follows

$$AMT_n = L\left[\frac{i(1+i)^{n-1}}{N}\right.$$

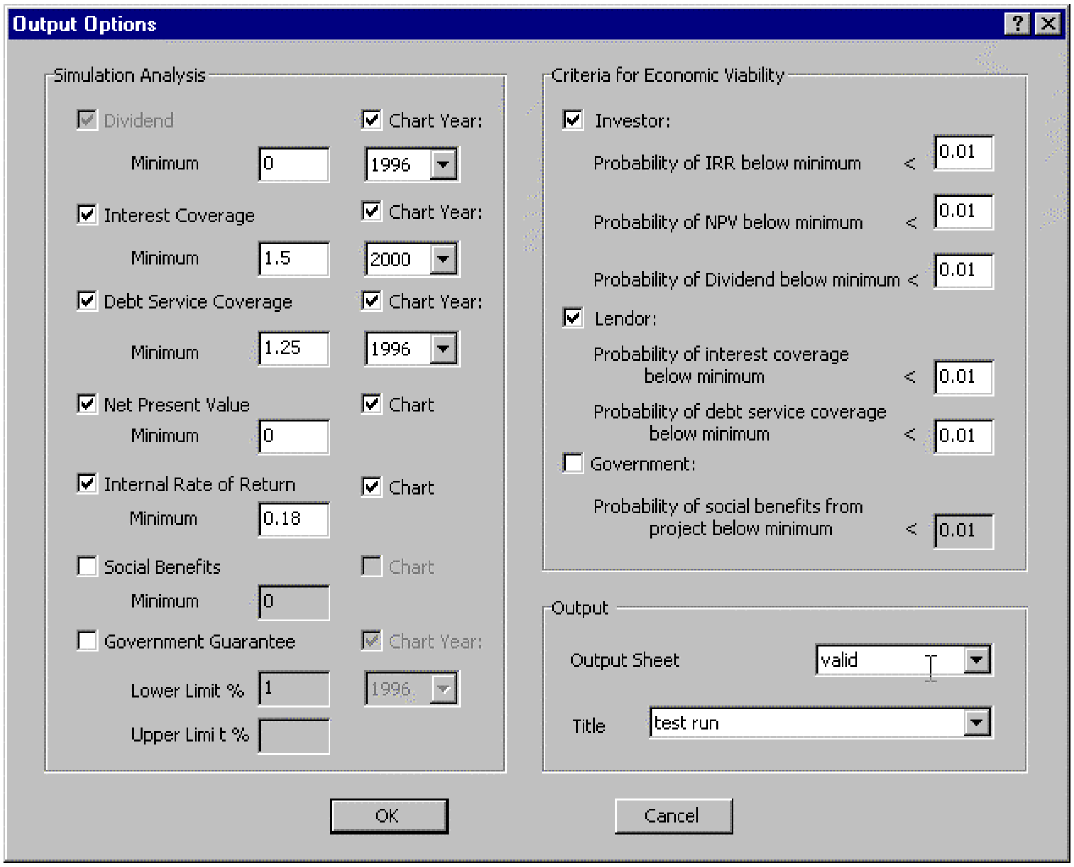
Equity Capital Info



The Equity Capital Info dialog is designed to permit the user to store and edit key information concerning equity capital in a project. Such information relates to the amount, currency, and disbursement plan over the construction phase of the project's equity.

III. Customizing and understanding the simulation output

Output Options Dialog



This dialog allows the customization of the two main types of output generated by *INFRISK*: (i) the *simulation analysis* and (ii) the *economic viability analysis*.

The *simulation analysis* provides information on the estimated probability that a given risk variable will be lower than a specified minimum level (denoted as "minimum" in the dialog). These estimates are calculated for each year of the project's lifetime. The user can also choose to generate charts showing the probability distribution estimates in a selected year for each risk variable. Figure 9 shows a sample *INFRISK* output sheet; examples of INFRISK's chart output can be found in Figures 3-6.

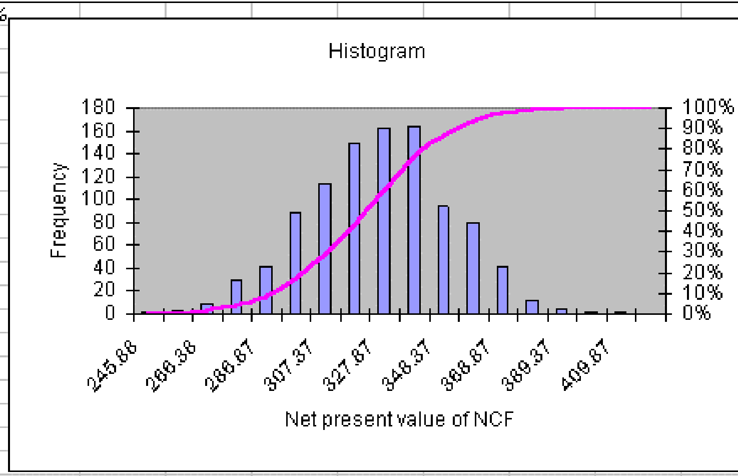
Figure 9: *INFRISK* Output Sheet

[illegible]t Run		1996	1997	1998	1999	2000	2001	2002	2003	2004
Number of iterations	1000									
Expected Dividends		8.002	9.542	8.950	7.418	6.710	6.685	2.850	3.337	2.375
Expected Cash Flow		118.362	120.151	119.357	116.717	116.705	115.216	110.663	113.189	113.085
Probability of Dividend below 0		0.176	0.186	0.227	0.264	0.312	0.300	0.439	0.399	0.435
Expected Value of Debt Service Coverage		1.043	1.057	1.044	1.025	1.003	1.006	0.949	0.935	0.907
Probability of Debt Service Coverage Below 1.25		0.973	0.923	0.917	0.931	0.948	0.947	0.971	0.985	0.991
Expected Value of Interest Coverage		1.291	1.337	1.341	1.314	1.334	1.333	1.273	1.348	1.383
Probability of Interest Coverage Below 1.5		0.924	0.807	0.776	0.806	0.765	0.759	0.807	0.709	0.648
Net Present Value of Cash Flow	321.569									
Internal rate of Return on the Expected Dividends	N/A									

Charts of the simulation analysis can also be produced by checking the appropriate box, if desired. Figure 10 gives an example of the chart output for the distribution of the net present value of cash flow.

Figure 10: *INFRISK* Chart Output

sent value	Frequency	umulative %
245.88	1	.10%
256[illegible]3	3	.40%
266.38	9	1.30%
276.62	29	4.20%
286.87	42	8.41%
297.12	89	17.32%
307.37	113	28.63%
317.62	149	43.54%
327.87	163	59.86%
338.12	164	76.28%
348.37	94	85.69%
358.62	80	93.69%
368.87	42	97.90%
379.12	12	99.10%
389.37	5	99.60%
399.62	2	99.80%
409.87	2	100.00%
More	0	100.00%



Summary	
Mean	321.117
Standard I	24.76
Median	321.766
Min	245.877
Max	409.867
Count	1000

The *economic viability analysis* can be undertaken from the perspectives of the parties involved in an infrastructure project: the project promoter (investor), the creditor, and the host government. This analysis will show whether the probability of a given variable meeting the specified criterion falls within the accepted confidence level. A “pass” result indicates that the estimated probability generated by the Monte Carlo simulation is below that specified by the user “confidence level.” The viability analysis provides the following options:

- *From the investor’s perspective:*
  - (a) Probability of the internal rate of return being smaller than a specified level.
  - (b) Probability of the net present value being smaller than zero should be smaller than the specified level.
  - (c) Probability of dividend being negative or smaller than the specified level.

- *From the creditor’s perspective:*
  - (a) Probability of the interest coverage ratio being smaller than a specified level.
  - (b) Probability of the debt service ratio being smaller than a specified level.

- *From the government’s perspective:*
  - (a) Probability of social benefits from the project being smaller than a specified level.

The economic viability analysis report provides the user with information on each particular constraint. The output explains why the project does not pass certain requirements. Figure 11 shows an example of the viability output.

Figure 11: *INFRISK* Economic Viability Output

Test Name	Test Result	Maximum Probability of Being Below Acceptable Level	Year of First Failure
Dividend	failed	0.978	1996
IRR test	NA		
NPV	passed	0.000	
Debt Service coverage ratio	failed	1.000	1996
Interest coverage ratio	failed	0.924	1996
Social Benefits	not selected		

Box 6: Computation of NPV and IRR in INFRISK

1. NPV. *INFRISK* calculates NPV in according to the following equation:

$$NPV = \sum_{i=1}^{c} (-1)\frac{ES_i + LS_i + BS_i}{(1+r)^i} + \sum_{i=1}^{o} \frac{NCF_i}{(1+r)^{i+c}}$$

Where c and o are the respective number of construction and operation periods, and

ES_i = Equity allocation during i^{th} construction period
LS_i = Loan allocation during i^{th} construction period
BS_i = Bond allocation during i^{th} construction period
NCF_i = Net cash flow associated with the project in i^{th} operating period
NCF = TOR-TOE-TAX+DEP (see also ANNEX 1)
r = a specified annual discount rate

2. IRR. The IRR function is closely related to NPV. It is the rate that equates NPV to a value of zero (from the point of view of the investor). However, the cash flow used for NPV and IRR in *INFRISK* is not the same. For IRR we use the Equity on the negative side and the Dividend on the positive side of the equation. The solution is found using the Excel built-in function which employs an iterative method that clearly depends on starting values. Theoretically, there may be as many solutions as the power of the respective polynomial; however, we solve for a local solution close to the assumed discount rate. If no solution is returned by the Excel IRR function, we indicate this situation by printing N/A in the corresponding cell.

Annex 1: Project Financial Accounts

Indiantown Cogeneration Project, selected years

A. Project Initial Capitalization (Construction Phase)

		1993
Bonds (disbursed in year)	BS	127.21
Equity (disbursed in year)	ES	30.32
Letters of credit	LCS	0.00
Loans	LS	0.00
Construction Costs	CK	109.68
Financing Costs during Construction	IK	9.89
Other capital expenditures	OK	49.85
Debt service reserve	DRK	0.00
Total Capital Expenditures	KS=CK+IK+DRK+OK	169.42
Ending Exch Rate	Et	1.00

B. Income-Expenditure Table

		1996
Operating Revenues	OR	185.45
Investment Income	INV	3.36
Total Operating Revenues	TOR	188.81
Operation and Maintenance	OME	11.55
Insurance and Administration	INSA	0.00
Fees on Loans	FEE	0.00
Other Expenses		14.59
Disposal Cost		48.49
Other Operating Expenses	OEE	63.08
Total Operating Expenses	TOE=OME+FEE+OEE+INSA	74.63
Interest Payment	INTP	57.69
Tax Withheld	WTX	0
Scheduled Amortization	SAM	8.80
Depreciation*	DEP	43.87
Income Before Taxes	INBT	12.62
Tax	TAX	3.78

C. Cash Flows Table

		1996
Income Before Taxes	INBT	12.62
Total Debt Service	TDS	66.49
Equity Funds	EF	140
Debt Funds	DF	675
Capital Expenditure	CKF=CK+OK	159.53
Loan Repayment	LAM	0.00
Bond Repayment	BAM	8.80
Credit Letter Repayment	LCAM	0.00
Debt Repayment	DAM=LAM+BAM+CAM	8.80
Tax	TAX	3.78
Operating Cash Flow	OCF=OR-OME-INSA	197.00
Net Cash Flow	NCF=TOR-TOE-TAX+DEP	177.26
Equity Cash Flows (Dividend)	DIV=TOR-TOE-TDS	47.69
General Account	GA	0.00
Debt Service Reserve Fund	DSR	0.00
Maintenance Account	MA	0
Exchange Rate	Xt	1.00

*In general DEP can be a non linear function of CK, ψ(CK)

Note: INV=$f(G,A,r)$ where r = applicable interest rate

Annex 2: Details on generation of random variates for Monte-Carlo Simulation

This section describes the computational methodology for generating the four classes of probability distributions – uniform, normal, lognormal, and beta – that are used in the Monte Carlo simulation adapted in *INFRISK*.

Uniform random variate

The uniform random variate *u* is generated using a built-in Excel function RAND. This function returns a (0,1) variable. To transform it with an error term possessing a required standard deviation, we first standardize *u* a by centering around the mean value of 0.5 and dividing by its standard deviation of $(1/12)^{0.5}$ such as

$$u^* = \frac{(u-0.5)}{\sqrt{1/12}}.$$

Then we multiply *u** by the desired standard deviation.

Normal random variate.

Following Maindonald (1984), we used the Marsaglia and Bray's polar method (a variation of Box-Muller method).

Step 1. Generate uniform (0,1) variates u_1, u_2. Transform them into $u_1=2u_1-1$, $u_2=2u_2-1$, so that new uniform variables will be distributed in (-1,1)

Step2. Let $w = u_1^2 + u_2^2$, if w > 1 skip and select a new pair of uniform u_1, u_2 until the restriction is satisfied.

Step 3 Set $v = \left(\frac{-2\log w}{w}\right)^{1/2}$, then set $z = u_1 v$ which will serve as a standard normal (0,1) variate that is further transformed by multiplying by the desirable standard deviation and adding the projected mean /trend.

Lognormal variate

The lognormal variate is obtained by first generating a normal variate and applying the exponential transformation to new series $y = \exp(\ln(\hat{Y}) + zs)$ where *z* is a standard normal variate. The user should bear in mind that when supplying σ for the lognormal distribution, he should convert it into a log scale himself.

Beta random variate

The beta random variate with parameters α and β is generated by using the following simple algorithm adopted from Maindonald.

Step 1 Generate uniform (0,1) variables u_1, u_2.

Step 2 Let $v_1 = u_1^{1/a} + u_2^{1/b}$

Step 3 if w=v1+v2 < 1 put x=v1/w. Otherwise, take new u1, u2. and go to Step 2.

INFRISK always assumes a = 2, b=5 because the resulting distribution is skewed to a reasonable degree, as was justified in some experiments. Thus, obtained beta variate is standardized by subtracting its mean and dividing by its standard deviation (see Box 5). The obtained standardized variate is further transformed by multiplying by the desirable standard deviation and adding the projected mean /trend.

Annex 3: Preparing data on projected variables in the Input Sheet

To perform analysis on her own data, the user should provide a sheet with certain variables for the construction and operation periods. We already mentioned that the projected values for the simulated variables can be stored in the input sheet. Also there are some other “non-risk” variables that can be stored in the input sheet.

It is important that the user follows the right format when entering the data in the input sheet. The first column will normally have the name of the variable of interest (optional), while the second column must contain the correct label of the variable, which is not optional. The third column must contain the identified units (currency). The US dollar should be specified as *USD*. The next columns are the data columns, which must contain the numerical values for the corresponding variables The data are split into two tables, one for the construction phase, the other for the operating phase. Each table must have a heading line that contains the year identifiers in the corresponding columns as well as table identifiers in the second column (see example in the Figure). Those are *YRCON* for the construction table, and *YROPER* for the operation table.

Sources of Uncertainty	Labels
Revenues	OR
Operations & Maintenance	OME
Other Operating Expenses	OEE
Investment Income	INV
Ending Exch Rate*	Xt
Interest Rate	Ir
Construction Costs /Equity**	CK/ES

* The exchange rate is a macroeconomic variable and the data should be provided for both construction (if it is not omitted) and operation period. In the former case, the label is Et, in the latter Xt. The exchange rate is always in terms of local currency/USD
**if the source of uncertainty is associated with construction costs, it also automatically makes equity random so as to balance sources and uses of the funds

The user can also store in the input sheet information on the ranges of all simulated variables. The labels for these data should follow the format: <variable label>RANGE; for instance, ORRange for the Revenues. This information will be used if the user selects the *Estimated from Projected Ranges* option for the error standard deviation of the simulated variable.

The following variables are not considered sources of uncertainty and are **optional.** If omitted in the input sheet they will be assumed to have a value of zero.

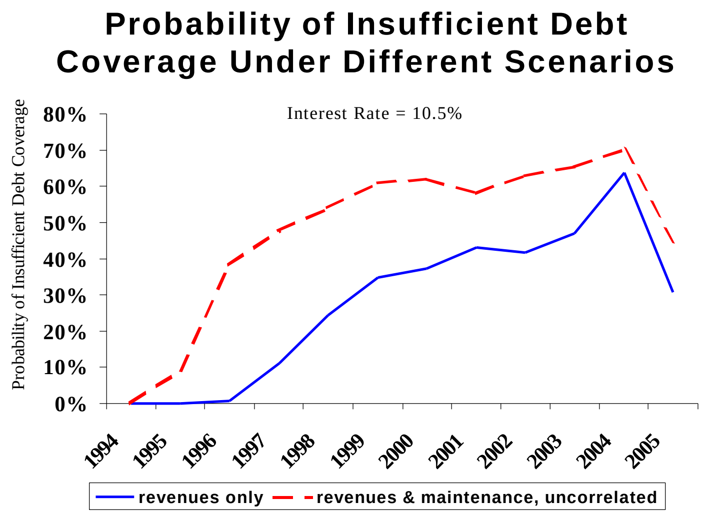
Non-random variables for the construction period	Labels
Debt Service Reserve	DRK
Other capital Expenditures	OK
Interest during construction	IrC
Exchange rate durung construction	Et
Financing Costs during	IK

Construction	
Non-random variables for the operation period	**Labels**
Insurance and Administration	INSA
Deposits to Major Maintenance Accounts	DMA
Withheld tax payment	WTP
Fees on Loans	FEE
Non-random part of the revenues*	NR

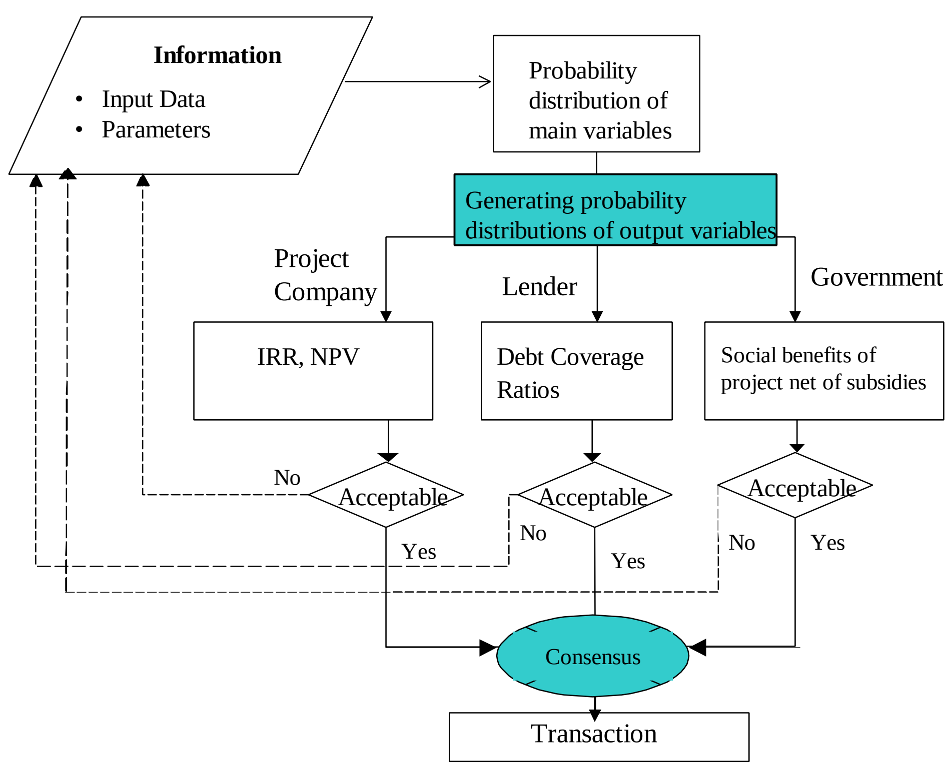
*This quantity will be added to the random part of the revenues in all subsequent calculations and is useful when we need to model the stream of revenues as consisting of two parts, one effected by random factors and the other fixed at certain level.

As was explained earlier, the user can also store in the input sheet information on the amortization schedules for the loans. The labels for these data should follow the format SAM<*loanname*>; for instance, if the name of the loan is LOAN1, then the information on the amortization schedule should be stored in the row labeled as SAM LOAN1. This information will be utilized by *INFRISK* when the user specifies the repayment plan as **Defined Schedule** in the *Parameters of the Debt Instrument* dialog.

Annex 4: Charts



<u>Flow chart diagram of *INFRISK*</u>



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