7-20-2004

Implications of Incorporating Risk into the Analysis of an Irrigation District's Capital Renovation Project

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This is the abstract of a presentation given on Tuesday, 20 July 2004, in session 2 of the UCOWR conference.

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Title: Implications of Incorporating Risk into the Analysis of an Irrigation District's Capital Renovation Project

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Water shortages in the Texas Lower Rio Grande Valley have prompted investigation and analyses of various means to increase the efficient use of the area's existing water supply and to develop new sources of water. Methods for increasing efficiency in and across the region's 29 independent irrigation districts include various capital renovation projects (e.g., canal lining, flow metering, pipeline) of different magnitudes and of different economic lives, as well as other water management-type projects, including wastewater treatment, desalination, etc. Due to funding limitations and the need to estimate and compare the economic performance associated with different projects, a means of evaluating and prioritizing these projects was sought. A spreadsheet model, Rio Grande Irrigation District Economics (RGIDECON©), was developed by Texas A&M economists (Rister et al. 2002) to provide the basis of a consistent means of project appraisal and to facilitate priority ranking of projects based on expected, deterministic, economic performance represented by the costs of anticipated water and energy savings. The structure of RGIDECON© has been formally approved by the Bureau of Reclamation (Walkoviak) and endorsed by the Border Environmental Cooperation Commission, North American Development Bank, and the Texas Water Development Board.

Like most capital investment analyses, RGIDECON© relies on precise mathematical calculations to assess the net present value (NPV) and annuity equivalent (AE) calculations of an investment project. The potentially imprecise point estimates used as input data in the analyses may flaw these calculations, however, leaving the analysis incomplete. The probability of reality and the calculated performance values actually equaling one another is close to zero due to the uncertainty surrounding the estimates of key input data concerning several years into the future. It is difficult to assess the impact of such variations in the data on a project's performance, the overall risk associated with a project, and the probabilities of different outcomes occurring for a project when using strictly deterministic or point estimate analysis without regard for risk.

The method of simulation, or stochastic modeling, as an evaluation approach for project appraisal under uncertainty seeks to solve this problem. Simulation was first described in the early works of Hertz and further incorporated by Reutlinger and Pouliquen in the analysis of capital investment projects undertaken by the World Bank in place of cost/benefit analysis in the early 1960's. Simulation involves assigning appropriate probability distributions to input variables containing uncertainty, accounting for correlation coefficients amongst these variables, and randomly and repeatedly selecting values from within the selected probability distributions to create a probability distribution for an entire project's performance considering the realistic

combinations of various events (Pouliquen). The risk associated with an individual capital investment project can be assessed from this distribution, and the probabilities of occurrence for various outcomes can be calculated.

A new spreadsheet model, Risk RGIDECON©, has been developed to increase the robustness of the original model, RGIDECON©. In Risk RGIDECON©, stochastic (rather than deterministic) values for the cost of water and energy saved are determined by using appropriately-defined probability distribution functions (PDFs) for risky input variables and simulations techniques as described recently by Richardson. The new model follows the standard financial and economic investment analysis methods presented in RGIDECON© and documented in Rister et al. (2002). More specifically, the spreadsheet's calculations enable a comparison of projects with different economic lives, among other important considerations. The methods used in the model assure for recognition of the social time value of money (and other resources), adjust the parameters of PDFs for cost projections to account for nominal increases in prices, and include discount rates that contain terms for both social time value and increases in relative nominal input prices, but ignore risk.[1] Additional refinements in Risk RGIDECON© include adjustments to the PDFs of key input variables for heteroskedasticity (i.e., increasing risk over time) and to maintain coefficient of variation stationarity (CV). Potential performances of proposed projects are presented in the form of a cumulative probability function (CDF) to display the range and probabilities associated with the costs of water and energy savings for each project.

The initial prototype of Risk RGIDECON© is demonstrated using the single-component, 72" pipeline, capital renovation project proposed by Hidalgo County Irrigation District No. 1 and previously evaluated with RGIDECON© (Rister et al. 2003). Input variables converted from deterministic values in the previous analysis to stochastic values for the project (Smith) include: (a) initial capital investment, (b) useful economic life of the investment, (c) increases in operating and maintenance costs (O&M), (d) decreases in O&M costs, (e) water savings (ac-ft), (f) energy usage (BTUs per ac-ft), and (g) cost of energy savings ($/kwh). Using Simetar© (Richardson et al.), a simulation add-in to Microsoft Excel©, Risk RGIDECON© generates the probabilities of achieving different real water and energy savings, as well as the economic and financial cost probabilities associated with those savings. Three different analyses are conducted on the project to illustrate the effects of marginal degrees of incorporating risk considerations into the project evaluation: (a) all input variables are considered to be independent (i.e., no correlation among the input variables is considered); (b) appropriate subjective correlations among the input variables are considered (i.e., intra-temporal correlation); and (c) intra-temporal correlations among input variables are considered, along with appropriate subjective correlations among similar variables between different years (i.e., autocorrelation or inter-temporal correlation).

In the original deterministic RGIDECON© analysis (Rister et al. 2003), the cost of saving one ac-ft of water was estimated to be $24.68. At first glance, the apparent impacts of evaluating the proposed capital investment project with Risk RGIDECON© with varying degrees of correlation realizes apparent lower estimates, with the mean cost savings per ac-ft of water for the three different sets of analyses being (a) $19.36, (b) $19.34, and (c) $19.38, respectively. These stochastically determined means are statistically equal at the 0.01 significance level. For the initial analysis (i.e., complete independence among variables), the calculated cost of water

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[1] Griffin notes that because of the potential federal funding component of the projects, it could be appropriate to ignore the risk component of the standard discount rate, as that is the usual approach for federal projects.

savings is estimated at $19.36 per ac-ft with a 90% probability that the cost will be between $10.91 per ac-ft and $26.69 per ac-ft (Figure 1). Consideration of correlation in analyses (b) and (c) introduces lessened variation in the projected cost estimates as illustrated in Figure 2. Statistical evaluations of the differences in the variation among the three different analyses results are significant at the 0.01 level. These results are summarized in Table 1. Similar types of results for the energy analyses are not presented here due to space limitations.

These results add another dimension to the appraisal and assessment of various capital renovation projects by incorporating risk associated with uncertainty into the analysis and by providing the probabilities of achieving different costs of water and energy savings. Instead of basing priority ranking of projects solely on the expected, deterministic, economic performance of the costs of water and energy saved, this analysis allows for a more in-depth priority ranking of projects while considering the uncertainty of data estimates for the various input parameters. With the potential risk of each project identified, various methods for ranking risky decisions (e.g., stochastic dominance) can be utilized to best prioritize projects based upon the risk aversion coefficients of the decision-makers involved (Richardson).

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Table 1. **Comparison of Risk RGIDECON© Results Considering Varying Degrees of Correlation Among Input Variables, Hidalgo County Irrigation District No. 1, 72" Pipeline Capital Renovation Project, 2004.**

Analysis	Description	Mean	Minimum	Maximum	Std. Dev.	90% CI	
						Lower	Upper
	Deterministic	$ 24.68	$ 24.68	$ 24.68	$ -	n/a	n/a
(a)	Stochastic - No Correlation	$ 19.36	$ 5.41	$ 32.82	$ 4.83	$ 10.91	$ 26.69
(b)	Stochastic - Intra-temporal Correlation	$ 19.34	$ 7.37	$ 30.66	$ 4.19	$ 11.86	$ 25.52
(c)	Stochastic - Intra- and Inter-temporal Correlation	$ 19.38	$ 7.12	$ 31.32	$ 4.21	$ 11.92	$ 25.71

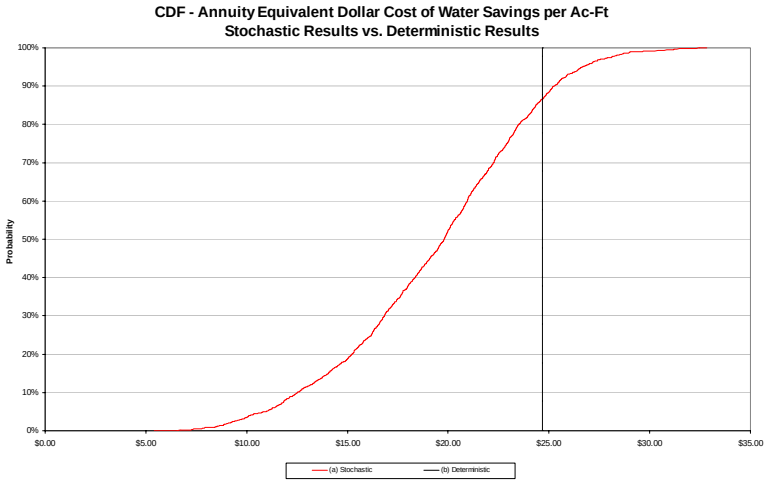

Figure 1. Comparison of Stochastic Independent Analysis Results to Deterministic Analysis Results.

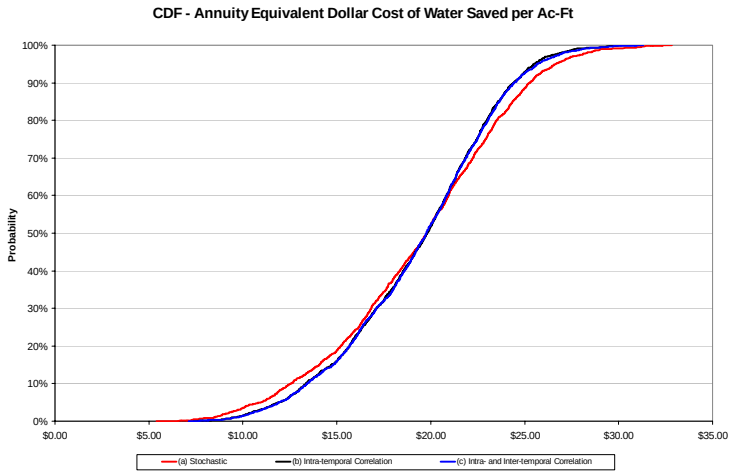

Figure 2. Comparison of CDFs for All Correlation Analyses.