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ECONOMIC RISK EVALUATION FOR RESIDENTIAL HOUSING PROJECTS

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ABSTRACT
The level of economic risk in construction projects is often great. Providing management with accurate assessments of the probabilities of project net present value outcomes could enable strategic decision making with explicit consideration of risk. Previous work focused on presenting a practical multi-factor approach to this problem, which would allow risk calculation with a minimum of user input and effort. The needs for accurate risk factor probability distribution curves, juxtaposed with the difficulty of eliciting data from management, solving complex activity networks, and accounting for real-world correlations, are dealt with in this continuing research. Accurate probability distribution curves for significant risk factors, such as project licensing and marketing, are currently being investigated: the potential impact of their use in improving risk analysis accuracy is explored. Lastly, an effective and accurate method for assessing the sensitivity of a project's net present value (NPV) to fluctuations in individual risk factors is presented.

KEYWORDS
Multi-Factor Economic Risk Analysis, Net Present Value, Sensitivity Analysis, Probability Distribution

1. INTRODUCTION

The uncertainties inherent in commercial construction projects make the decision to invest a difficult one. The difficulty is compounded by the fact that the methods in common use for assessing overall project risk do not accurately reflect the compound influence of the many uncertain factors involved. In many cases, the uncertainties could be reduced by management action; but this is predicated on having reliable indications of where such action (which usually requires additional expense) will have most effect. Sensitivity analyses currently in use are particularly misleading, and while more complex computation methods are available, they are not in everyday use mainly due to their complexity and the fact that they require a great deal of risk input from managers.

We present a practical, multi-factored approach to calculating the distribution of the probablitity of the Net Present Value (NPV) of an investment in a construction project. Minimal information is required from the project manager, since typical distribution curves may be selected for each uncertain risk factor. These curves may be standard symmetrical or skewed distributions, or pre-prepared distribution curves representing the historical behavior of certain common risk factors (such as construction duration and marketing period). The calculation method takes into account any correlations between risk factors that the user specifies. Correlations may be positive or negative, and may vary in strength. A new method for determining the sensitivity of the project NPV probability distribution to the fluctuation of individual risk factors is also presented. With the results of these calculations, a manager may simulate the effect of any particular action s/he deems necessary to reduce the risk level of the project (i.e. to increase the probability of achieving some particular goal, such as obtaining positive NPV or a minimum return on investment). The established research into methods for calculating NPV probability distributions are presented in the next section. Then, the newly developed multi-factor method is explained. An example, based on a residential real estate project, is presented. Lastly, the method and application of an accurate sensitivity analysis is detailed.

2. METHODS FOR CALCULATING NPV PROBABILITY DISTRIBUTIONS

It is useful to express the uncertainty of the result (in terms of cost, duration or a combination of them) of an engineering project in the form of a cumulative probability distribution function (CDF). A number of research projects have investigated ways to calculate the CDF for either the duration or the cost of projects. Relatively few efforts have been made to rigorously combine duration and cost risks so as to assess the CDF for the overall worthiness of a project, which is usually expressed as the Net Present Value (NPV) or Internal Rate of Return (IRR) for a commercial venture.

2.1 Assessing Uncertainty in Project Schedules

The PERT method enabled assessment of the stochastic probability of completing a project in any given time, where projects were modeled as networks of activities with sequency relationships between them. An important characteristic of activity networks is that there are usually many logical paths from the first to the last activities (the Critical Path Method - CPM - solves activity networks for their longest path). When uncertainty is introduced in the duration of each activity, there may be no single 'longest' path under all possible circumstances. Also, correlations may exist between the durations of similar activities, thus exacerbating the project's uncretainty. For these reasons, the PERT method consistently undersestimates project durations for complex projects. An improved method, called PNET (Probabilistic Network Evaluation Method) was proposed by Ang et al (1975). It models risk dependence between paths using a transitional correlation coefficient. Ranasinghe (1994) refined the approach by using an activity-on-node network and including skewed distributions (lognormal) for activity durations. These are all analytical methods and in fact approximate the true result. Simulation techniques, such as Monte-Carlo simulation, can also be used (Keefer and Bodily, 1983). Due to the enormous quantity of computations typically required in simulation (individual activity durations must be generated for every activity and the activity network must be solved at every iteration), researchers have traditionally used simulation only to validate analytical methods (Ang et al, 1975).

2.2 Assessing Uncertainty in Project Costs

Dependencies between the costs of different construction work packages is common (Touran 1993). For example, low productivity of a particular resource, say a tower crane, will adversely affect the cost of all work packages which make use of that resource. If such dependencies are neglected in computing the cumulative probability distribution of total project cost, the average cost will not be affected, but the risk at the extremes will be underestimated (Diekmann, 1983). Analystical methods and simulation methods may be applied; Touran (1993) incorporates risk dependencies in a Monte Carlo simulation scheme by constructing a correlation matrix, which is used to weigh the random values for each correlated cost item at each calculation iteration. Wang and Huang (2000) proposed extending cost risk calculations to include schedule related risk dependencies between work packages. The durations of work activities which have overlapping schedules are considered, and the covariance between them is weighted toward the preceding activities.

2.3 Difficulties and Inaccuracies in NPV Risk Assessment

The major obstacles to effective risk analysis cited in the literature are the difficulties associated with problem formulation and elicitation of input data from project management (Ranasinghe and Russell 1993, Ye and Tiong 2000). In specific terms:

- Setting the discrete probabilities expected over a range of values for each significant risk factor is not practical for project managers (Benjo 1999).
- Selecting standard distributions (such as those from the Pearson system – Johnson et al 1963) for risk factors may be misleading, since many risk factors have asymmetrical and non-continuous behaviors (Touran 1993). On the other hand, statistical records of variation in the behavior of risk factors are often either unavailable or difficult to adapt to the local conditions of specific projects.

- Formulating any specific project risk analysis in the terms required by the available computational methods, such as building matrices of covariance, is percieved as problematic.
- Risk calculations which ignore dependencies, or which cannot be effectively manipulated to test 'what-if' scenarios for risk management, are not considered useful.

As a result, very simple risk sensitivity analyses, in which the impact of each risk factor is considered in isolation, remain the most common form of risk assessment for construction project investments.

3. THE MULTI-FACTOR METHOD

The goal of the multi-factor approach to risk analysis (Warszawski and Sacks 2001) is to provide a straightforward method for assessing risk in construction investment projects, at different levels of information about the variability of project risk factors, so as to enable controlled management activity to reduce risk. To overcome the problems listed above, the method must:

- allow operation with only the basic information available to the decision maker,
- use simple computational tools,
- employ simple and easily understood procedures, yet enable realistic expression of varying project circumstances.

Activity networks form the basis of the method. All common precedence relations between activities are supported. A duration and a cost (or income) may be associated with each activity in the network. Activities which model payments or receipts only may be given zero duration. The Net Present Value of the project in any given state is determined in three steps: first, the network is solved, then the NPV of each activity cost is determined on the assumption that the cost is incurred at the midpoint of its duration (this is sufficiently representative of most construction contract disbursement patterns, but could be changed where necessary), and lastly the NPV values are accumulated.

The duration or cost of any of the activities may vary through a range of uncertainty. Uncertain costs or durations are termed 'risk factors'. The probability of a risk factor having any specific value is described using a probability distribution function (PDF). Selection of an appropriate function is simplified using the following procedure:

1) If only the most likely value for a risk factor can be elicited, one of two symmetric distributions can be selected, **Normal** or **Triangular**, and given a set range of variation. In selecting a symmetric distribution, the user implicitly assumes that the most likely value is exactly halfway between the minimum and the maximum.
2) If the minimum and maximum values of the parameter can also be elicited, one of two available skewed distributions should be used, **Beta** or **Skewed Triangular.** The elicited 'most likely' value is assumed to be the *mode*, not the *mean*, as is consistent with the assumption of simplicity and with most previous projects (Keefer and Bodily, 1983, Ranasinghe and Russell, 1993). This value sets the position of the peak of the distribution.
3) If detailed information is available, or where investment in eliciting accurate data is justified, specialized discrete or continuous distributions can be used. This is demonstrated later in this paper.

The Probability Distribution Function (PDF) of each risk factor R_i (cost or duration) is divided into *k* equal intervals, and the probability of occurrence $p(R_i)$of the middle value of each interval is calculated as the area below the PDF over the interval (figure 1). Any particular outcome *z* for the project as a whole, NPV_z , can then be calculated by computing the NPV with a set of particular values for each of the *n* risk factors (a set of R_{iz}). Assuming (initially) no correlation between risk factors, the probability of achieving that outcome, $p(NPV_z)$, is the product of the interval probabilities of each of the risk factors (formula 1):

$$p(NPV_z) = p(R_{1z}) * p(R_{2z}) * p(R_{3z}) \ldots\ldots p(R_{nz}) \qquad (1)$$

The PDF for the project as a whole can be calculated in one of two ways: sampling, using Monte Carlo Simulation, or enumeration, using a procedure similar to the Controlled Interval and Memory method (Cooper and Chapman 1987). In enumeration, a 'decision-tree' structure results, as shown in figure 2. This is solved using a recursive algorithm to traverse the branches of the tree. The number of calculations is potentially very large (k^n) – this is discussed in detail in Warszawski and Sacks (2001).

Positive or negative linear risk dependencies between any two risk factors can be modeled. The user is required to rate the degree of dependence ρ using a simple scale from 0 to 1 (or –1 to 0). The probability of occurrence of a particular interval value k_B of a risk factor B (e.g. the cost of site overheads) $p'(k_B)$, which is dependent on some other risk factor A, (e.g. the duration of construction) is adjusted using the formulae:

$$p'(k_B) = \rho \mid [k_B = k_A] + (1-\rho) * p(k_B) \quad \text{for} \quad 0 \le \rho \le 1 \tag{2}$$

$$p'(k_B) = -\rho \mid [K+1-k_B = k_A] + (1+\rho) * p(k_B) \quad \text{for} \quad -1 \le \rho < 0 \tag{3}$$

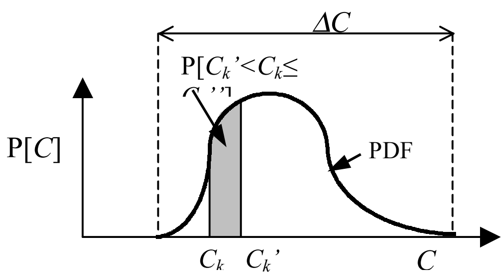


Figure 1: Interval Probability under Probability Distribution Function for a Risk Factor *C*.

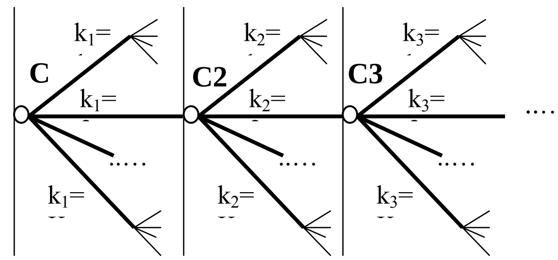


Figure 2: Decision Tree for Generation of Events.

Once the Cumulative Distribution Function (CDF) for a project is plotted, the NPV at the requisite level of certainty can be read. If the risk is unacceptable, resources can be allocated in an attempt to reduce the risk. The procedure can be repeated until a satisfactory policy is reached. This process can be guided by assessing the impact of individual risk factors on the whole project, with all of its comlpexity and uncertainty, using the method proposed in Section 5 below. The method described above holds the advantage of being straightforward and simple to use. The basic model is almost identical in its setup to that of activity network models common in construction management; it can be operated with different degrees of knowledge of risk factor variation for each risk factor; and lastly, the user need only set simple risk dependencies between those activities where they are presumed to exist. The method has been implemented as a Visual Basic® application. The software is launched using Microsoft Project®, which also provides the CPM activity network solver. The results are plotted using Microsoft Excel®. The system has been tested using complex projects as test cases, including a large scale three stage housing project (Warszawski and Sacks, 2001).

4. INCORPORATING HISTORICAL BEHAVIOR PATTERNS FOR RISK FACTORS

4.1 Case study – Basic Risk Assessment for a Commercial Housing Construction Project

Data were collected for a number of typical housing projects to allow exploration of the effect of incorporating realistic risk factor probability distributions for basic risk factors on the overall project NPV probability distribution. A simple 18 unit housing project case study is used here to illustrate the findings. This project was undertaken in the town of Zikhron Ya'akov in Northern Israel between 1998 and 2001 by a medium-size property development and construction company. The values for the risk factors that were used for the case study (most likely, minimum and maximum values for each risk factor) were elicited from the company's MANAGER shortly after the project was begun. The simplified project activities, and their attendant risks, are listed in Tables 1, 2 and 3. In conformance with guidelines developed through previous experience with the method (Warszawski and Sacks 2001), Beta distributions were applied to each risk factor.

The risk dependence information in Table 3 can be read as follows: The cost of the 'Sales' (advertising, marketing, sales office and staff, and associated expenses) are dependent on the duration of the 'Sales' activity with inverse proportion (i.e. the longer the sales take, the more expensive it will be). Also, the income from sales is somewhat dependent (25% correlation) on the duration of the sales (i.e. the longer the sales take, the more the sale price is likely to decline). The cumulative NPV distribution curve resulting from this analysis is shown in figure 4. Two individual results should be noted: the probability of achieving NPV ≥ $0 is 82%, and the NPV achieved with a certainty of 50% is $98,600.

Table 1: The Case Study Project Activities

Activity ID	Description	Predecessors	Most Likely Duration	Most Likely (Cost) / Income
1	Purchase Land		0	($1,180,000)
2	Preliminary Design and Permit	1	26 wks	($38,000)
3	Detailed Design	2	17 wks	($75,000)
4	Construction	3	95 wks	($1,791,000)
5	Sales	3FS+4wks	60 wks	($125,000)
6	Income Payments - Deposits	5	0 wks	$1,925,000
7	Income Payments - Transfer	4,5	0 wks	$1,925,000

Table 2: The Case Study Project Duration Risks

Activity ID	Description	Minimum Duration	Most Likely Duration	Maximum Duration	Risk Dependence
2	Preliminary Design and Permit	13 wks	26 wks	39 wks	
3	Detailed Design	13 wks	17 wks	22 wks	
4	Construction	78 wks	95 wks	104 wks	
5	Sales	26 wks	60 wks	104 wks	

Table 3: The Case Study Project Cost Risks

Activity ID	Description	Minimum Cost	Most Likely (Cost) / Income	Maximum Cost	Risk Dependence
3	Detailed Design	($100,000)	($75,000)	($70,000)	
4	Construction	($2,000,000)	($1,791,000)	($1,650,000)	
5	Sales	($220,000)	($125,000)	($100,000)	5, Duration, -1
6	Income Payments - Deposits	$1,750,000	$1,925,000	$2,050,000	5, Duration, -0.25
7	Income Payments - Transfer	$1,750,000	$1,925,000	$2,050,000	6, Cost, 1

4.2 Using Historical Data to Predict Risk Factor Distribution Patterns

As is common in most such projects, while the company project manager could estimate minimum, most-likely and maximum values for the risk factors involved, he was unable to determine their expected *patterns of variation*. It has been shown (Warszawski and Sacks 2001) that the shape or pattern of a risk probability distribution function can significantly influence the resulting CDF of a risk calculation. In many cases, previous experience, either of the same owner or of others in previous and comparable projects, may be brought to bear. In particular, statistics gathered over a large sample of projects may be applied in computing realistic approximations for risk factor distributions.

It is important to distinguish between assisting a manager with estimating the minimum, most-likely or maximum *values* of a risk factor, and assisting with estimating the *shape* of the distribution (i.e. the *behavior* of the risk factor). In some cases, usually activity durations, an assessor will most easily predict the minimum and most likely outcomes – it is the behavior and maximum value that usually present difficulties. In others, usually activity costs and incomes, the minimum and maximum values may be easier to determine, while the behavior (i.e. distribution shape), and hence the most-likely value, are unknown. While no two entire projects are ultimately alike, given the combinatorial numbers of possible outcomes, it can be assumed that the *distribution pattern* of results for a single risk factor, for a statistically large sample of like construction projects, will reasonably accurately reflect the possible outcome for the risk factor in a new project. Local geographical, technical, market and seasonal influences relevant to the particular site and period of the project considered are taken into account in that the minimum and most-likely values, or the minimum and maximum values, elicited from the project management, are retained: the historical distributions are mapped accordingly.

To illustrate the potential impact of using historical data, a hypothetical historical time to sale distribution curve was assumed (figure 3a). This can be mapped to the minimum and maximum values elicited from the project manager (figure 3c), in place of the beta distribution assumed when no historical data is available (figure 3b). The implication is that the most likely value predicted by the distribution will be shorter than that predicted by the project manager, i.e. that the historical distribution is more reliable than the project manager's perception of the distribution. Performing the analysis using this distribution for time to sale rather than the beta distribution results in the curve shown in figure 4. The difference in the probability of achieving NPV=0 is 9%, which is of a magnitude potentially sufficient to change the initial investment decision.

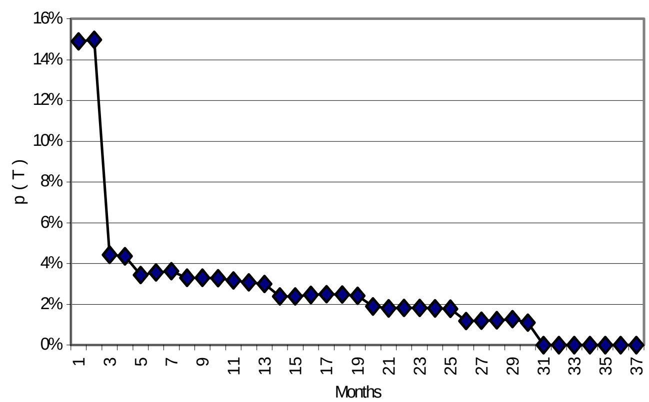
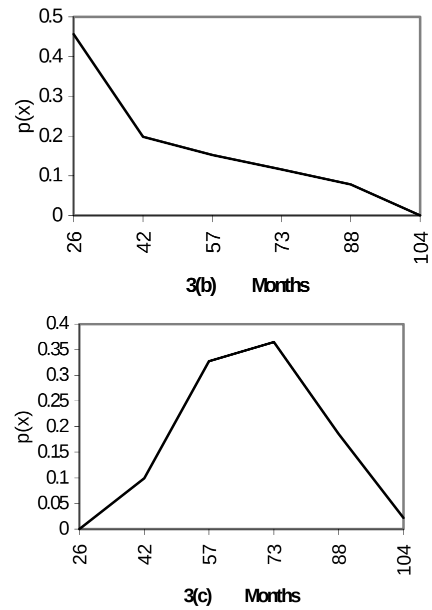


Figure 3a: Hypothetical Time to Sale Historical Data for Housing Projects.



Figures 3b & 3c: Beta and Historical Probability Distributions for Time to Sale for Housing Projects.

5. ACCURATE SENSITIVITY ANALYSIS

The raison d'etre of risk analysis of this type is not simply to calculate risks, but to simulate the effect of management actions in reducing risk. In projects where the calculated level of risk is unacceptable, management may consider taking action to lower the risk inherent in one or more risk factors. Such action usually requires additional investment or resources, and so should be applied where it can be most effective. Traditional sensitivity analysis simply requires calculating the range of influence of each risk factor while the values of all the other risk factors are held at their most likely values. This method can neither explore the true effect of each risk factor, nor can it be effective in assessing the overall levels of risk inherent in the project.

An improved method of assessing the risk influence of individual risk factors is proposed as follows:

1) Establish all of the parameters required for running a multi-factor risk analysis as described above, and run the analsysis, producing a cumulative NPV distribution.
2) Select a risk factor for sensitivity analysis, and then fix the value for that risk factor only at its most likely value.
3) Perform the analysis as before, producing a new cumulative NPV distribution.

The difference between the two distributions describes the effect, at any level of risk required, of neglecting the risk factor concerned. In this way, the true impact of a risk factor on an already risky system can be evaluated. For example, consider sensitivity of the case study project to risk of fluctuations in sales price. Using a traditional sensitivity analysis, the minimum NPV is a loss of ($92,000), while the maximum that can be earned is $334,000 (the no risk NPV is $146,000). This gives no indication of the likelihood of the NPV being below 0$. On the other hand, the method proposed above results in the curves plotted in figure 5. It is worth noting that the sales price carries significant risk in the event that the project is only marginally successful (low NPV range) (the added risk at the 80% confidence level is $60,000). This implies that any action that a manager could take to raise the minimum expected price (by improving the size or finish specification of the apartments, for example) could have significant impact on reducing the risk level. Ameliorating the minimum sales price risk can also significantly increase the most pessimistic project outcome. The third curve in figure 5 shows the new project NPV result after an investment of an additional $45,000 in construction costs, with a corresponding rise in the minimum sale price, but no increase in the maximum sale price.

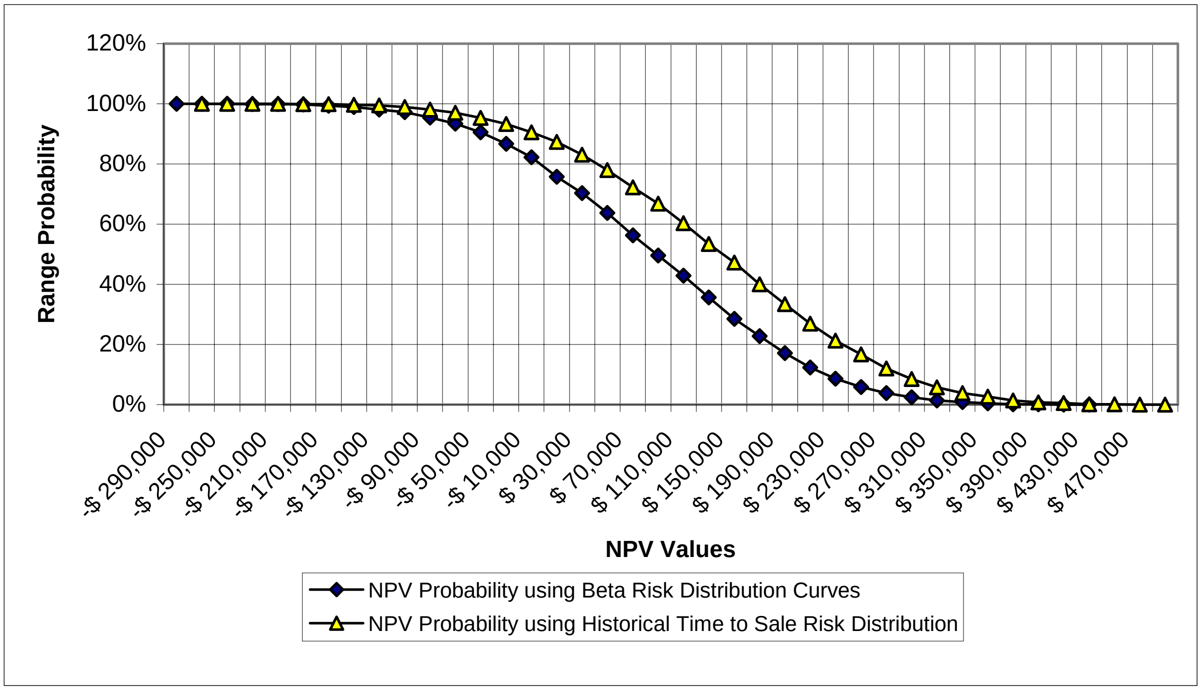


Figure 4: Multi-Factor Risk Analysis using Historical Distributions

The method should be used with caution in any situation where the most-likely value of a risk factor, used for the risk analysis without that factor, is different from the modal value of the risk probability distribution curve used for the full risk analysis (i.e. with that factor). This can only arise when the elicited 'most-likely' value is abandoned in favor of a full curve from historical data. In such cases, the difference between the curves may be largely attributable to the difference in most-likely values alone.

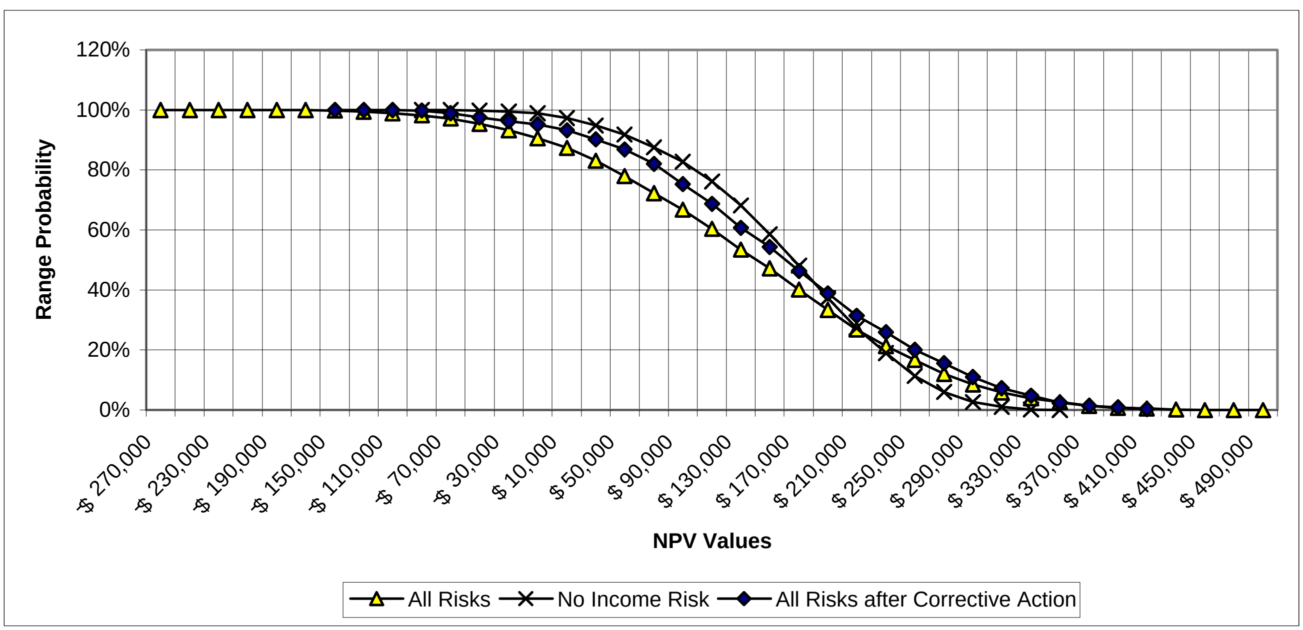


Figure 5: Multi-Factor Sensitivity Analysis

6. CONCLUSIONS

The multi-factor approach to assessing risk in construction projects (Warszawski and Sacks 2001) has been tested in the domain of commercial housing construction projects. The method has significant advantages in that it overcomes the complexities of use associated with other methods. It is simple to use, and can effectively model correlations between risk factors. The use of distributions based on historical data should be investigated further. The following potential improvements are possible:

- the system is easier to use when pre-prepared distributions are available, since no effort is necessary in selecting and calibrating an arbitrary distribution.
- it is likely that the confidence of management in the results would be enhanced.

Risk analyses are most useful if they can simulate the effect of actions which may be taken by management to reduce risks. The multi-factor approach enables such simulations with simplicity. The proposed method of sensitivity analysis can be used to identify potential high-impact actions. The method can provide more useful information to project managers than can the sensitivity analysis method currently in use in the industry (which gives only a rough indication of the range of impact of any risk factor taken in isolation). The method gives not only the accurate range of impact, but provides the impact on the project outcome at any given level of risk throughout the range. The effect of neglecting a particular risk is given within the correct context of all other risks, rather than the isolated impact of considering only the particular risk while neglecting all others.

7. ACKNOWLEDGMENT

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