

SIMULATION BASED PROJECT SELECTION DECISION ANALYSIS TOOL

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ABSTRACT

Project Selection is the process of evaluating individual projects, to choose the right project based on an analysis so that the objectives of the company will be achieved. It involves a thorough analysis including the most important financial aspect to determine the most optimum project among all the alternatives. Some projects have high uncertainty, and therefore simulation based project selection decision analysis could evaluate the projects with a greater confidence. The model presented in the paper shows a special purpose simulation tool for project selection based on influences that govern the project selection process. A graphical and hierarchical approach is adopted for the non-simulation experts to use the model to derive the expected results for project selection process and decision making under uncertain conditions.

1 INTRODUCTION

In any thriving organization, the number of potential projects will far outweigh the capital dollars available. Therefore, selections of those projects that have the greatest value to an organization is extremely important to ensure that the company sustains the operations and grows in the selected strategic direction. The process of "project selection" is normally based on a set of criteria determined by the organization, which may range from purely economic project drivers to subjective issues such as production, marketing, personnel, administrative, etc. This paper discusses a framework for project selection decision analysis

utilizing a Special Purpose Simulation (SPS) tool developed by Hajjar and AbouRizk (2000). The decision framework presented in this paper allows an organization the ability to quickly and effectively graphically model the independent economic variables and influences in the form of an influence diagram. The SPS tool is tailored to project selection and re-selection analysis considering statistical decision uncertainties using Monte-Carlo analysis.

2 PROJECT SELECTION PROCESS

The selection of the right project for future investment is crucial for the long-term survival of the company. The selection of the wrong project may well precipitate project failure. Project selection is ultimately the responsibility of senior management, whose decision should be based on informative data (Burke, 1994). Although the financial point of view of project appraisal is the main basis for evaluation, there are various other considerations. Meredith and Mantel (1995) documented the areas of production considerations, marketing considerations, personnel considerations, and administrative considerations in addition to financial considerations.

There are various methods available in terms of numeric and non-numeric models to offer a wider portfolio of project selection techniques. The model explained in this paper is a numeric model using Monte Carlo simulation based financial analysis. If the results of financial analysis for project selection are to be satisfactory, the amount of uncertainty should be reflected in the input data. When relationships between inputs and outputs in the projects are

complex, Monte Carlo Simulation can handle such uncertainty by exposing the many possible consequences of embarking on a project (Meredith and Mantel, 1995). In this approach, probability distributions are used instead of point estimates of the input data for each of the uncertain variables. Because of these stochastic inputs, the probability distribution for the output such as Net Present Value (NPV) or Internal Rate of Return (IRR) is then usually found by simulation. According to Meredith and Mantel (1995), the decision maker not only has probabilistic information about the output (NPV, IRR) and future cash flows but also gains knowledge about the variability of such estimates as measured by the standard deviation of the financial returns.

3 MODELING OF PROJECT SELECTION DECISION ANALYSIS

Historical Modeling Developments date back to 600 BC – when Thales and Pythagoras developed Geometric modeling. More recent modeling developments include probabilistic modeling and performance modeling and analysis. However the practical application of such modeling tools are generally nonexistent in corporate boardrooms. Instead corporations tend to rely on an array of historical analytical tools and experience to guide them through the decision making process. Decision factors and prioritization of potential projects are often based on subjective criteria and uncertain or ill-defined risk factors. The project selection model presented herein attempts to provide a “bridge” over this gap using a graphical Monte-Carlo based probability assessment of the decision influences (Arsham 2002, Web).

The project selection decision-making process provides the organization the information required to make a decision with knowledge of the degree of confidence inherent in the decision. The features and functions of the project selection decision analysis process include:

- Identification and analysis of projects or project alternatives,
- Identification of the activities, resources, and constraints of the strategic projects,
- Depiction of the projects in a symbolic form for modeling, (influence diagram),
- Identification of the model inputs and outputs from the analysis,
- Explanation of how the model will optimize the inputs, and
- Explanation of how the outputs are generated by the model.

3.1 Influence Diagram

In order to depict the relationships between the influences relative to the desired output, an influence diagram is a

widely accepted tool. The influence diagram for a typical project selection decision, Figure 1, shows all of the identified inputs to the analysis. The inputs are independent variables that have an influence on the outcome of the analysis. The input data for these influences are developed as part of the project investigation and development work undertaken by an organization’s project team. The independent variables, or inputs, to the influence diagram may be either deterministic or stochastic. Unless a statistical analysis is performed, such as a Monte-Carlo analysis, the inputs are typically deterministic. For a statistical representation of the project Net Present Value, stochastic inputs are required.

4 STRUCTURE AND THE LAYOUT OF THE SIMULATION MODEL

The structure of the simulation template using Symphony, special purpose simulation engine, adopted the graphical and hierarchical elements to depict a flexible structure using three levels. This was done in accordance with the structure of the influence diagram shown in Figure 1 as well. The uppermost level, the parent of the SPS model is analogous to the “Global Influences” shown in Figure 1. The independent variables that influence all of the layers of the model are input in at the parent level. They are inflation rate, discount rate, and corporate tax rate. The SPS model parent level modeling element and input screen are shown in Figure 2.

At the first child level of the model, multiple project alternatives may be analyzed concurrently. The inputs at this level are project specific parameters that affect all of the project influences. This is limited to the project duration.

The second child level depicts the modeling elements, customized elements for dollar inputs of the independent variables according to the outer layer of the influence diagram. The model input parameters are listed and explained in Table 1. The modeling elements and input parameters were selected to be specific to the economic factors relating to a project economic analysis, while providing flexibility. The flexibility is available in the ability to add any number of the modeling elements to a project specific influence diagram, utilizing the capital cost, Research & Development Cost (R&D), Operating Cost, Revenue and tailor the “Other Cost” element to suit a project specific cost or saving.

The calculations performed by the model are based on the projected project cash flow. The model inputs include the timing of the project cash flows, both revenue and cost. The model calculates the yearly cash flow profile over the life of the project. The output statistic, that is the basis of the project selection decision, is the NPV of the project cash flows. By calculating the NPV over the entire life of the project, the decision makers have an approximation of the life cycle cost of the entire project. An investment with

an NPV of zero means that the project will pay for itself at the discount rate used in the calculation. A positive NPV means that the project will yield a return greater than the discount rate. The NPV calculation use in this model is the sum of the present values of the yearly net cash flows, or;

$$NPV = \text{Sum}((\text{Yearly Cash Flow}) / (1 + \text{Discount Rate})^{\text{year}})$$

The yearly cash flow also considers the corporate tax and equipment depreciation in the calculation. The model is configured to allow staged timing of cash flows, such as

- R&D spending start and duration
- Capital spending start and duration
- First Year of operation, which impacts the operating cost and revenue cash flow timing.

For illustration purposes, values for the input parameters have been selected and listed in Table 2. The values have purposely been selected to demonstrate the features a decision-maker would look for in the analysis of the available options, the range of possible outcomes and the risk profile for the project or alternative. When the input para-

eters are being developed and considered by the project team, the distribution and the uncertainty of data is considered for the parameters that are not constant. By performing a Monte Carlo analysis on the information collected, we can get a sense of the project’s risk profile (Hartman, 2000). The data presented in Table 2 differs between Alternatives 1 and 2 only in the range of the estimated costs and revenue. Alternative 1 has a considerably wider range in the data, which is a reflection of the uncertainty in the values. A large variance in the input ranges for a capital project may be attributable to several reasons, but it mostly reflects the lack of scope definition.

4 SAMPLE ANALYSIS

The critical output from this model is the NPV statistics. A corporation may manually perform a deterministic NPV calculation for any project under consideration. This single value does not lend much information about the confidence level of the calculated NPV value or the range of possible outcomes. By performing a stochastic analysis of the decision variables, the decision maker has a significantly larger amount of information available for consideration.

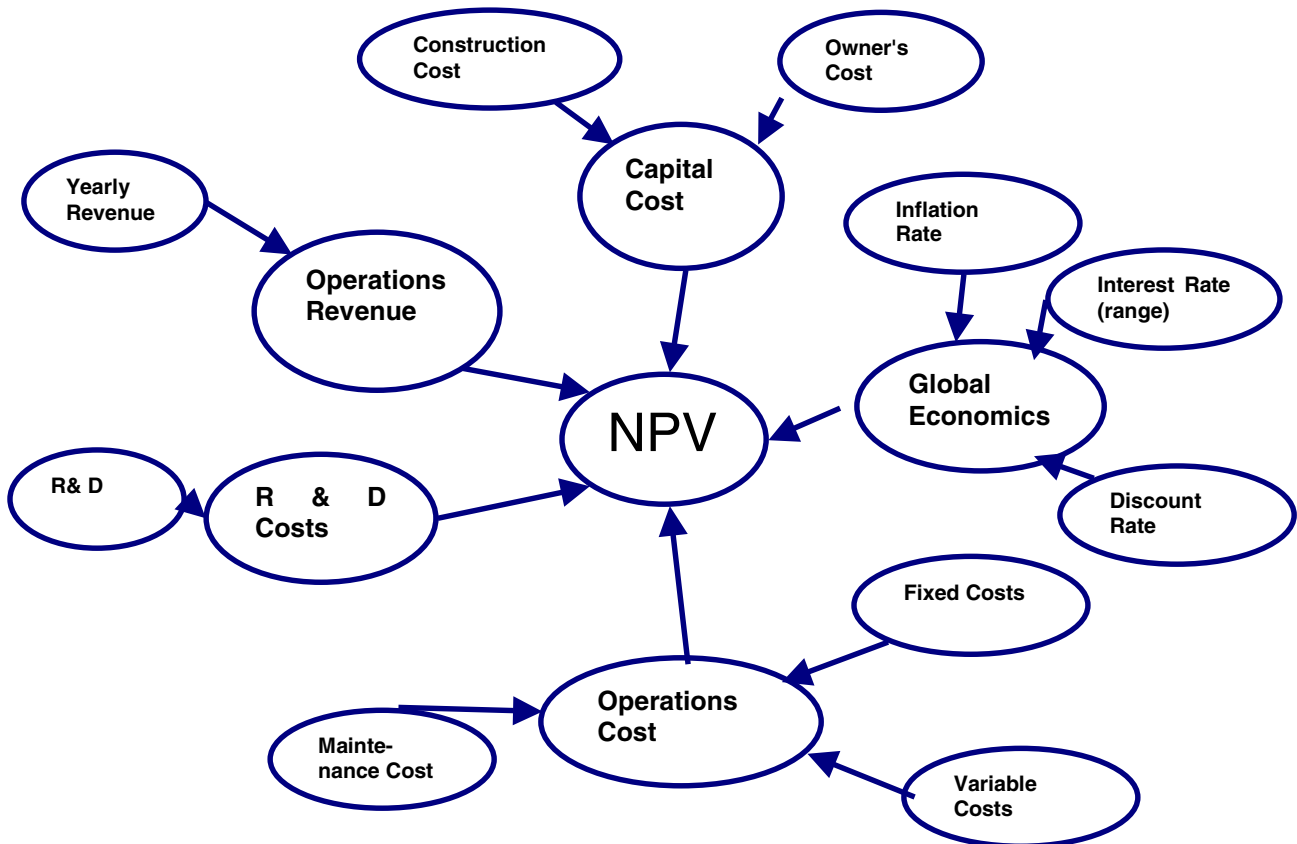
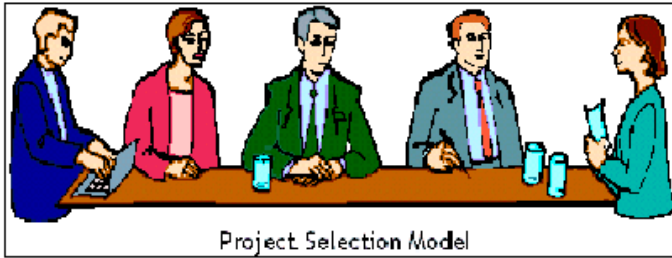
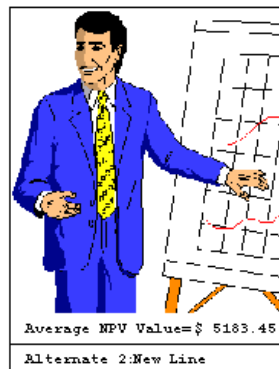
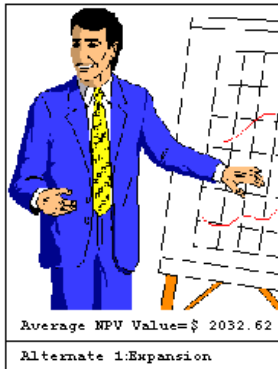


Figure 1: Typical Project Influence Diagram



Parent Level:
Global Project Influences



Child Level #1:
Multiple Alternatives

Child Level #2:
Project Influence Diagram

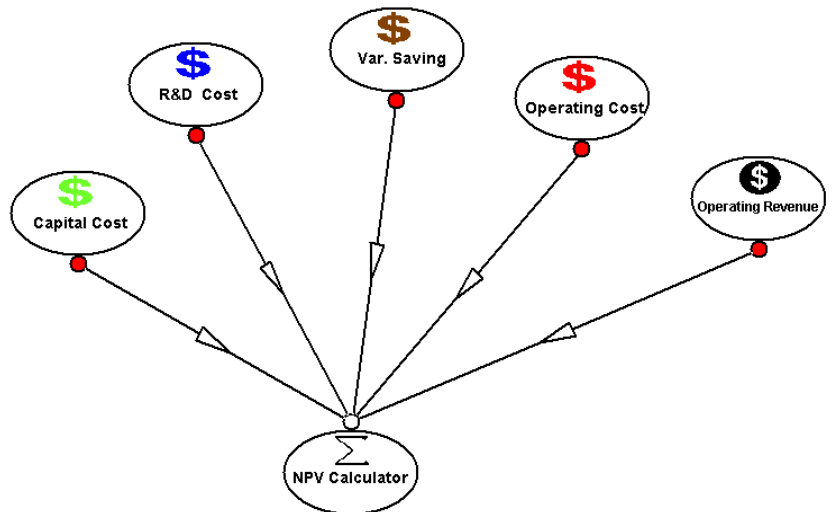


Figure 2: Layout of the Simulation Model

Table 1: Project Selection - Parameter Input Description

Modeling Element and Input Fields	Explanation of Input
Parent Level: Global Influences	
Inflation Rate	Predicted inflation rate over the life of the projects
Discount Rate	Corporate investment discount rate; used in the NPV calculations
Corporate Tax Rate	Marginal corporate tax rate
No. of Projects / Alternatives	Calculated by the model based on the number of alternatives
Child Level #1 - Alternatives	
Alternative Description	Description of the alternative or project under consideration
Project Life Span	Economic life of the project
Child Level #2 - Capital Cost	
Description	Element description
Equipment Cost	Stochastic values for estimated capital cost
Construction Cost (direct/indirect)	Stochastic values for estimated construction indirect/direct cost
Material Cost	Stochastic values for estimated material cost
Engineering Cost	Stochastic values for estimated engineering cost
Owner's Cost	Stochastic values for estimated owner's costs
Other Costs	Any other capital related costs
The first year capital is spent	Timing of the capital cost expenditures for the project
Number of years in which the capital is spent	Number of years the funds will be spent
Child Level #2 - R & D Cost	
Description	Element description
Estimated R & D Cost	Stochastic values for estimated R&D Expenditures
The first year funds are spent	Timing of the R&D expenditures for the project
Number of years in which the funds are spent	Number of years the funds will be spent
Child Level #2 - Other Cost	
Description	Element description : Var Saving
Fixed Cost	Estimated Fixed Cost change per year of the project life
Variable Cost	Estimated Variable Cost change per year of the project life
The first year funds are spent	Timing of the R&D expenditures for the project
Number of years in which the funds are spent	Number of years the funds will be spent
Child Level #2 - Operating Cost	
Description	Element description
Yearly Fixed Operating Cost	Estimated fixed operating cost change per year of the project life
Yearly Fixed Maintenance Cost	Estimated fixed maintenance change per year of the project life
Variable cost of Goods / Feedstock	Change in the cost of feedstock or cost of good for the project
The first year of operation	Number of years the funds will be spent
Child Level #2 - Operating Revenue	
Description	Element description
Estimated Operating Revenue in the first year	Estimated incremental increase in operations revenue
The first year of operation	First year the project will be operational and producing revenue
Child Level #2 - NPV Calculator	
Description	Element description

Table 2: Example Project Parameter Input Table

Modeling Element and Input Fields	Alternative 1			Alternative 2			Units
	Low	Median	High	Low	Median	High	
Parent Level: Global Influences							
Inflation Rate		3%			3%		%
Discount Rate		12%			12%		%
Corporate Tax Rate		19%			19%		%
No. of Projects / Alternatives		2			2		each
Child Level #1 - Alternatives							
Project Life Span		10			10		years
Child Level #2 - Capital Cost							
Equipment Cost	1000	1500	2500	1250	1500	1750	\$000/year
Construction Cost (direct/indirect)	1000	2000	3000	1750	2000	2500	\$000/year
Material Cost	550	1000	1500	800	1000	1100	\$000/year
Engineering Cost	700	750	1200	700	750	1100	\$000/year
Owner's Cost	500	1250	1500	1000	1250	1300	\$000/year
Other Costs		500			500		\$000/year
The first year capital is spent		2			2		year #
Number of years in which the capital is spent		2			2		year #
Child Level #2 - R & D Cost							
Estimated R & D Cost	500	750	1500	750		1000	\$000/year
The first year funds are spent		1			1		year #
Number of years in which the funds are spent		1			1		year #
Child Level #2 - Other Cost							
Fixed Cost		0			0		\$000/year
Variable Cost	-100		-50	-100		-50	\$000/year
The first year funds are spent		3			3		year #
Number of years in which the funds are spent		1			1		year #
Child Level #2 - Operating Cost							
Yearly Fixed Operating Cost	250		300	250		300	\$000/year
Yearly Fixed Maintenance Cost	80		100	80		100	\$000/year
Variable cost of Goods / Feedstock	250	1000	1250	750	1000	1100	\$000/year
The first year of operation		4			4		year #
Child Level #2 - Operating Revenue							
Estimated Operating Revenue in the first year	1250	5000	5800	4500	5000	6000	\$000/year
The first year of operation		4					year #
Child Level #2 - NPV Calculator							

The mean and standard deviation of the calculated NPV along with the cumulative probability curve may then be compared to the other available options. This stochastic information is important when comparing project alternatives that appear to have comparable deterministic NPV's, but one of the alternatives may have a considerable amount of uncertainty in the calculated NPV number. This would become apparent when the above analysis is performed, with the decision likely tending toward the project with the least uncertainty. The statistical output for the analyzed alternatives is shown in Table 3.

Of particular interest in the statistical output is the significant difference in the mean and the standard deviation. This information is invaluable when analyzing project al-

ternatives. Alternative No.2 is by far a much better option than the first. If a deterministic analysis of the same data was undertaken, it is conceivable that Alternative 1 may appear to be as economically attractive as Alternative 2, with an ill-informed decision would be required likely based on "gut-feel" or experience of the decision-maker.

Review and analysis of the cumulative probability (CP) curves for the NPV statistics, provides a powerful graphical representation of the range of project outcomes and the uncertainty, hence risk, inherent in the project decision.

The CP curve for Alternative 1 is shown in Figure 3. The wide range of possible project outcomes is readily apparent when compared with Alternate 2, shown in Figure 4.

Table 3: Simulation Output

Strategy Description	Minimum NPV	Mean NPV	Maximum NPV	Global Standard Deviation
Alternative No. 1	\$ (1,412)	\$ 2,331	\$ 5,137	\$ 1,066
Alternative No. 2	\$ 3,883	\$ 5,148	\$ 6,270	\$ 341

NPV of Alternative - All Runs

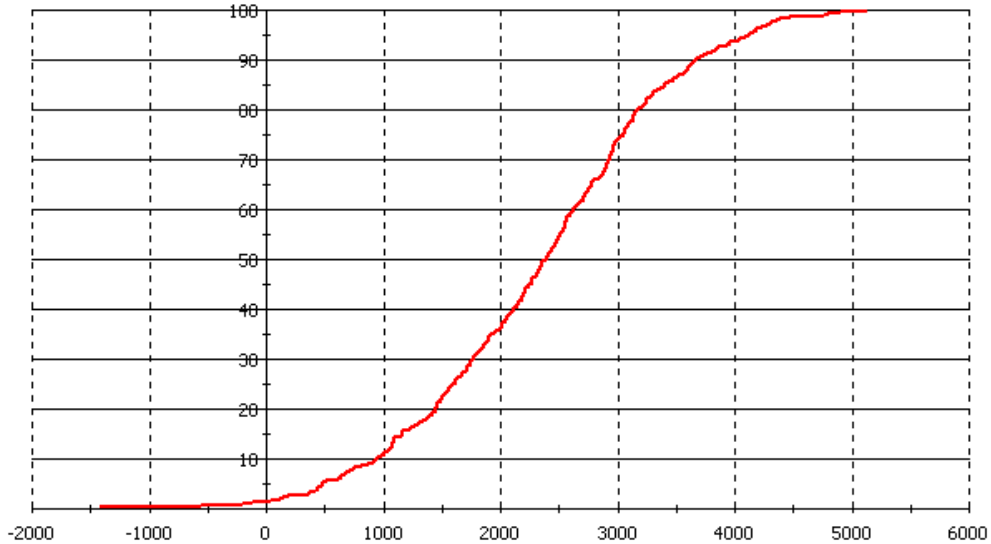


Figure 3: Cumulative Probability for NPV – Alternate # 1 (X-axis is the NPV, Y-axis is the cumulative probability)

NPV of Alternative - All Runs

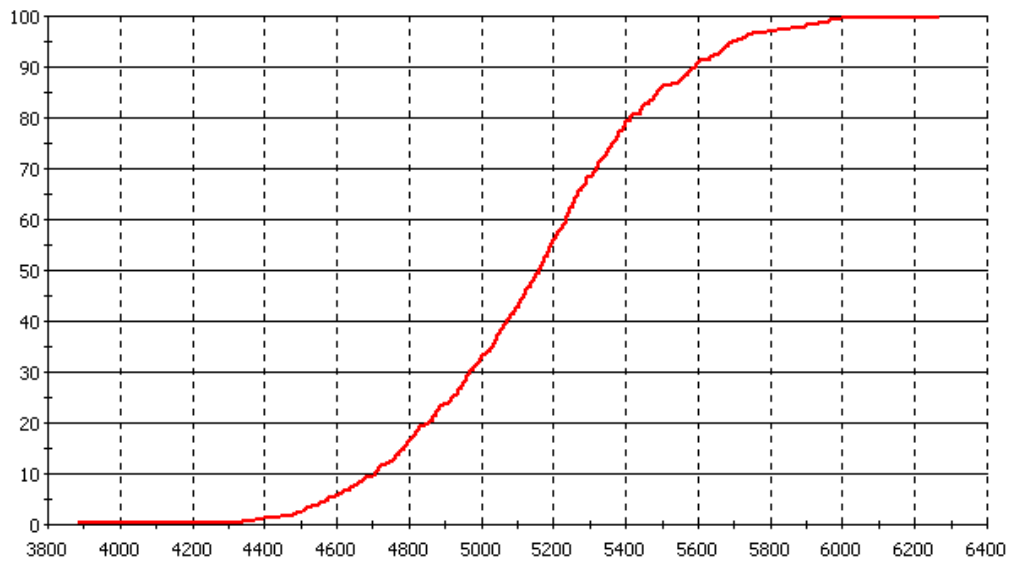


Figure 4: Cumulative Probability for NPV – Alternate # 1 (X-axis is the NPV, Y-axis is the cumulative probability)

5 SUMMARY AND CONCLUSIONS

The advantages to modeling a project selection situation, as with any decision under uncertainty, is that it takes a great deal of the guesswork and emotional rationale out of the decision analysis.

The output is valuable information that provides some of the following benefits:

- A statistical, risk sensitive basis to analyze available project alternatives
- A specified confidence in the expected outcome expressed in terms of the probability
- A powerful communication tool that is easily understood and expresses the range of outcomes and risk contained in the decision

The SPS project selection tool presented in this paper provides the framework for statistical modeling of the decision process and provides increased decision clarity, an understanding and communication of the decision risks and the expected outcome of the decision. The principles shared may be readily applied to the corporation boardroom and the daily project decision analysis in any organization.

REFERENCES

- Arsham, Hossein. Probabilistic Modeling: Decision Analysis, Higher Level Systems Ltd (http://www.asistum.com/2002/solutions/knowledge_management/knowledge_management.htm), [last accessed on May 13-2002.]
- Burke, R. 1994. *Project Management: Planning and Control*, 2nd Edition. John Wiley & Sons.
- Hajjar, D. and S. AbouRizk, 2000. "Application Framework for Development of Simulation Tools", *Journal of Computing in Civil Engineering*, 14(3), 160-167.
- Hartman, F. 2000. *Don't Park Your Brain Outside: A Practical Guide to Improving Shareholder Value with Smart Project Management*. Project Management Institute.
- Meredith, J.R. and S.J. Mantel. 1995. *Project Management: A Managerial Approach*. John Wiley & Sons.

AUTHOR BIOGRAPHIES

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