Risk Evaluation and Decision Modelling in Logistics Projects Using a Software Tool

Dimitrios M. Emiris\textsuperscript{1}, Panagiotis V. Siskos\textsuperscript{1} and Dimitrios V. Siskos\textsuperscript{2}

\textsuperscript{1}Department of Industrial Management and Technology, University of Piraeus
80 Karaoli & Dimitriou Str., 185 34 Piraeus, Greece

\textsuperscript{2} School of Management, City University of Washington State (in Collaboration with Technological Educational Institution of Piraeus, Greece)

Abstract— The decision of optimum location in the construction of a logistics (warehouse & distribution) center (or similar facilities) is frequently encountered in the business environment. On a purely logistical level (assuming minimal internal political considerations), this decision must take into account the uncertainties in the calculation of the transportation costs from the central location to peripheral (satellite) stores, the operating costs, the required capital investment and the cost of transportation subject to gas price fluctuations. This article addresses the above questions using an adequate software tool, and provides the methodological framework for the modelling of such business decisions; furthermore, it demonstrates the feasibility and the reliability of the proposed approach and corroborates its findings with a realistic example.

Keywords— Distribution Center, Uncertainty, Transportation, Optimization, Risk Management, Monte Carlo Simulation, Crystal Ball

1. INTRODUCTION

A common problem encountered in the logistics ecosystem, is to decide where to locate a warehouse and distribution center. Such projects involve not only a significant construction and infrastructure cost, but also considerable recurring costs, grown rapidly as the business turnover grows. These costs, however, are largely influenced by the operation and transportation costs components, which in turn, are a function of the distances covered (thus influenced by the highly fluctuating gas prices) and of the wages of the involved personnel. Proper project feasibility and viability analyses require careful examination and insight on the product life-cycle and not only on the construction project life-cycle itself. The minimization of risk in the decision, is therefore a result of proper scenario analysis in the design and project initiation phase. In our approach, we present a systematic and coherent framework for this problem, by using an adequate software tool for risk modeling, namely the Crystalball software [1, 2]. The software provides functionalities to model probabilistically the risk sources and their expected behavior, as well as Monte Carlo simulation tools, to evaluate the distribution of the outcome, along with tornado diagramming tools to rank risks and uncertainties.

In particular, the problem we examine and model herein is described as follows. A major logistics firm is interested to establish a new distribution center in Greece. Following a thorough market research the management of the firm has created a short-list of three potential locations in different prefectures (namely, Thessaloniki, Larissa and Attica). There also exist ten (10) satellite locations which receive deliveries from the main distribution center, at a different weekly rate. The calculation of total weekly Distance involves a Distance Factor which accounts for detours, deleterious road conditions, and indirect routes from the main distribution center to each satellite store (Figure 1).

![Distribution Center and Satellite Stores](image-url)

\textbf{Figure 1: Distribution Center and Satellite Stores.}

2. MONTE CARLO SIMULATION AND THE CRYSTALBALL SOFTWARE TOOL

Future estimates are not facts but statements of probability about how things will turn out. Because estimates are probabilistic assessments, costs may actually be very different than estimated even by seasoned professional estimators. The reasons are often causes that are outside the control of the manager, but may also be endemic to the estimating process, or the corporate culture. Uncertainty about a situation can often indicate risk [3]. Almost any change, good or bad, poses some risk. A typical analysis usually reveals numerous potential risk areas: overtime costs, results if geological survey, personnel fluctuations, changing labour costs, government approvals, etc. Once the risks are identified, a model can help quantify the risks, that is, to put a price on risk, to help decide whether a risk is worth taking. Traditionally, spreadsheet analysis tried to capture this uncertainty in one of three ways: Point estimates, Range estimates and What-if scenarios. There are several ways to perform a risk analysis, but one method involves building a spreadsheet model, which can be very helpful in identifying where the risk might be, since cells with formulas and cell references identify causal relationships among variables.

One of the drawbacks of conventional spreadsheet models, however, is that only one value can be entered in a cell at a time. This is where Monte Carlo Simulation and Crystal Ball (CB) S/W come in. A model is a spreadsheet that has taken the leap from being a data organizer to an analysis tool. A model represents a process with combinations of data, formulas, and
functions. As one adds cells that help better understand and analyze data, the data spreadsheet becomes a spreadsheet model. CB helps define those uncertain variables in a whole new way: by defining the cell with a range or a set of values. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables over and over to simulate a model. Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce [4]. Without simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modelled system [5].

For each uncertain variable (one that has a range of possible values), one may define the possible values with a probability distribution. The type of distribution that is selected is based on the conditions surrounding that variable. With CB, these equations are automatically calculated; CB can fit a distribution to any historical data that one might have. A simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. During a single trial, CB randomly selects a value from the defined possibilities (the range and shape of the distribution) for each uncertain variable and then recalculates the spreadsheet. The probability distributions that describe the uncertainty surrounding specific input variables are referred to in CB as "assumptions".

3. MODELING OF THE PROBLEM

The parameters that are considered as influencing the operation of the logistics center are considered to be the transportation and operational costs. For each site, the costs of transportation and operation as well as the capital investment vary. The management assumes that the Gas Prices, Number of Employees, Years of Operation, KwH per Year and Electricity Costs are not affected by the selected location. This is depicted in the Model Parameters worksheet (Figure 2).

In the present paper, we have built a model in order to calculate the total cost of each potential location incorporating uncertainty distributions for each uncertain variable using the Crystal Ball s/w. In the Model worksheet, the Distance Factor for each satellite store is modelled as a Uniform distribution that ranges continuously between 1 and 2 (Figure 3). This accounts for the uncertainty of travel between any two destinations by adding potential kilometres as a result of detours and indirect routing.

Additional assumptions in the Model Parameters worksheet related to uncertainties around wages, costs, investments, and resources. Each assumption will be different based on the underlying data used to define the uncertainty around the variable. For example, Gas Prices can fluctuate, and a lognormal distribution describes the possible prices ranges and probabilities for this resource (Figure 4).

In the model depicted in Figure 5, one can select the distribution center from the group of the three candidates to be examined. When testing each location (through Monte Carlo simulation with 10,000 runs), the model recalculates the Distances for the satellite stores and populates the costs cells (Row 5) with data from the Model Parameters sheet. The resulting distribution illustrates the average Total cost of each distribution center, subject to the modelled assumptions. During
a simulation, Crystal Ball saves the values in the forecast cells and displays them in a Forecast Chart, which is a histogram of the simulated values. By testing each center, the Attica location appears to offer the lowest Total Cost (Figure 5). But given uncertainty in the underlying costs, is this really true?

To view which of the assumptions had the greatest impact on the Total Cost, we use the Sensitivity Chart (Figure 7). Which assumptions most affect this forecast? Is this an assumption that can be addressed thus reducing uncertainty in calculations?

<table>
<thead>
<tr>
<th>Potential Location</th>
<th>Results without simulation</th>
<th>Results With Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thessaloniki</td>
<td>500.376.351,57 €</td>
<td>543.573.554,00 €</td>
</tr>
<tr>
<td>Larissa</td>
<td>508.207.007,49 €</td>
<td>550.946.857,00 €</td>
</tr>
<tr>
<td>Attica</td>
<td>500.131.245,43 €</td>
<td>544.240.655,00 €</td>
</tr>
</tbody>
</table>

5. SIMULATION USING OPTQUEST

When examining problems such as the present one, the CB software offers a powerful tool that simplifies the final decision. This tool is called Optquest (Quest of the optimal solution) and requires that at least one simulation of the model is run. OptQuest requires decision variables (Figure 8), which are model variables over which the user has control. The three decision variables defined in this model will have a value of either 0 or 1. Each decision variable is highlighted in yellow.
OptQuest starts from the Run menu. The OptQuest Wizard is used to define the settings for the optimization. The problem has one constraint (one of the three centers can be selected at a time) and one objective: to minimize Total Cost (Figures 9 and 10). The options are defined in a separate screen (Figure 11).

Once the settings are defined, Optquest is ready to start the optimization. For each optimization, OptQuest selects a new value within the defined range of each decision variable (e.g., a 0 or a 1) and runs a Crystal Ball simulation. OptQuest then saves the mean Total Cost value. OptQuest then runs another simulation on a new set of decision variables. OptQuest repeats this process, constantly searching for the lowest Total Cost until it either works through every possible solution or reaches the end of the set running time. In this model, there are only three possibilities, so the model runs quickly. As OptQuest runs, it uses multiple metaheuristic methods and techniques to analyze past results and improve the quality and speed of its process.

Once OptQuest is finished, one can copy the optimal results back to the spreadsheet through the Copy to Excel option in the Edit menu. The spreadsheet now displays the optimal solution, and Crystal Ball displays the forecast chart for the simulation from the best optimization. The OptQuest's Solution Analysis tool can be used to review the other optimization results.

6. RESULTS AND DISCUSSION

In the present paper we have demonstrated the feasibility of using a forecasting and risk analysis program to complement management decisions in projects where the product life-cycle needs to be carefully examined and evaluated. The analysis and the estimation of the uncertainties may be executed not only at the beginning of a project, but also in its middle stages. As the project develops, uncertainties become reality and decisions obtain specific values. But in the beginning of such projects there are multiple uncertainties, possible scenarios and lack of accurate information. This is exactly where the Crystal Ball software allows the management team to take the initial and most important decisions in conditions of relative safety, as a properly built model offers huge amount of information about the variables that affect the project. The presented model incorporates the uncertainty in the cost variables of running a distribution center so as to select its optimal location. The developed program has many more capabilities, thus allowing the definition of more parameters in a more complex model, as well as to calculate the correlation of the assumptions in order to build a model with more independent variables.

The Crystal Ball is an analytical tool that helps executives, analysts, and others make decisions by performing simulations on spreadsheet models. The forecasts that result from these simulations help quantify areas of risk so decision-makers can have as much information as possible to support wise decisions. The basic process for using Crystal Ball is to: 1. Build a model that reflects an uncertain scenario. 2. Run a simulation on it. 3. Analyze the results. The simulation of our model has resulted to the optimal decision incorporating uncertainties, has helped to analyze the multiple variables and encourages the use of the method for further applications in similar problems.

7. REFERENCES