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IT Investment Decision Making: A Decision Analysis Cycle Model

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ABSTRACT

Organizations spend substantial capital budgets on IT investment in order to achieve potential competitive advantages. However, IT investments are characterized with complexity, uncertainty, and risk. These attributes make appropriate IT investment decision making a challenging task. Decision analysis cycle methodology is a conceptual framework that facilitates achieving clarity of action in difficult decision problems. In the present study, this methodology is explained and applied on an imaging system investment of a mortgage bank to investigate how it can tackle complexity, risk and uncertainty in IT investment decisions.

Keywords

IT investment, decision analysis, decision analysis cycle, risk, uncertainty.

INTRODUCTION

The Organizations widely consider information technology (IT) as an essential means of achieving business value and competitiveness. This has resulted in their substantial allocation of budgets to IT investments. However, inappropriate investment in IT can cause competitive disadvantage and bring considerable unwanted cost to organizations (Schniederjans et al., 2004). IT investment decisions are characterized with complexity due to multiple possible solutions. In addition, there are various factors associated with the successful result of each solution. These factors may also be interdependent. Uncertainty is the other characteristic of IT investment decisions. The outcomes are usually uncertain or difficult to predict. Besides, the information about the influential factors on each outcome may be incomplete, unavailable, or unclear that makes the decisions risky.

In this study, we explain decision analysis methodology to show how it can facilitate tackling these difficulties in decision making under risky, uncertain and complex situations. Decision analysis provides a logical procedure to make the best decision based on the available information. The methodology will be also applied on a modified version of a case discussed in (Balasubramanian et al., 2000) paper using DPL7 software.

CASE DESCRIPTION

A mortgage bank called National Mortgage Trust (a pseudonym), NMT, is involving in a large IT investment. NMT, starting as a relatively small financial institution with an increasing asset from zero to \$6 billion over seven years, is regarded as being competitive in utilizing innovative processes for acquiring market share and offering attractive mortgage packages. NMT is devising a plan for mass customization. Through customization of mortgages to be directly delivered (not through mortgage brokers) to end-users with various needs, NMT seeks to increase its market share. To achieve this goal, NMT managements decide to start long-term direct relationships with their customers along with providing high quality service for them. However, the high quality service will require the availability of the customers' records upon their contact with NMT (e.g., via phone call). In order to succeed in providing such long-term high quality relationships, all relevant documents (e.g., customer records) should be retrievable by computers. Top management team determines imaging systems as the required technology for conversion of documents to soft copy images. NMT's imaging system investment is the decision making problem in present study (Balasubramanian et al., 2000).

RESEARCH METHODOLOGY

The term "decision analysis" was first introduced in 1965 by Ronald A. Howard (Howard, 1966). Decision analysis builds upon the two fields of decision theory and system analysis to provide a logical decision making procedure. The procedure accounts for the decision uncertainties and the decision maker's risk preference using utility theory and subjective probability

respectively. It also includes other influential decision factors appropriate for each specific decision problem (e.g., technical, or environmental factors) (Howard, 1968). The primary goal of decision analysis is helping the decision maker to achieve clarity of action (Howard, 2007). It facilitates identification of the best decision. However, it is important to distinct between a good decision and a good outcome. A good decision may be taken based on the available information and a logical procedure, but the result may turn out to be good or bad. The reason lies in the uncertainties that are beyond the control of the decision maker, but the selection of the good decision enhances the chance of meeting the good outcome (Howard, 1966).

Decision Analysis Cycle

In decision analysis discipline, the conceptual framework for progressive analysis of a decision is called decision analysis cycle or procedure. Basic decision analysis cycle comprises of three distinct phases: 1) deterministic, 2) probabilistic, and 3) information phases (Howard, 1968). The idea in decision analysis cycle is to continuously omit the variables that are not essential in the final decision (Howard, 2007). These phases can be repeated upon collection of new information or end with the best identified course of action. In the remainder of the present study, we elaborate decision analysis cycle and apply it to the NMT imaging system investment decision to demonstrate how it can help to effectively structure and resolve IT investment decision problems.

Deterministic Phase

The first phase of decision analysis is the deterministic phase in which a formal description or model of the decision problem is developed. A deterministic sensitivity analysis (without considering any uncertainty) is then carried out to specify the important factors influencing the decision. The model specification begins with bounding the decision by determining its alternatives. The alternatives are the different possible courses of action to address the decision problem. The next step is to assign values to the different outcomes of the alternatives (e.g., profit in a business decision can be a measure of outcome). Then, the state variables (i.e., variables affecting the outcomes that are not under the control of the decision maker) are determined. The nominal values of state variables and the range of their possible values are also identified. After that, a value model that captures the relationship among state variables and their connection to outcome values is specified. Finally, the time preference of the decision maker is identified (a simple example is an appropriate discount rate). This is required if the result of the decision will be realized during a long time (Howard, 1966; Matheson & Howard, 1984). In the following the formal description of the NMT decision problem is provided.

Decision Model

Alternatives

For imaging system investment, the NMT management is considering the following four alternatives

- Just conducting a pilot implementation of an off-the-shelf software imaging system in a limited number of offices for new mortgages
- After accomplishing the pilot investment, expanding the imaging system to all offices and converting old mortgage documents to soft copies
- All-around implementation of the imaging system from the beginning, without a pilot implementation
- No image system implementation

Outcome values

The value of each alternative is going to be measured using the following Net Cash Flow formula.

$$\text{Net Cash Flow} = (\text{market share} \times \text{Total market demand}) - (\text{Fixed cost} + (\text{variable cost} \times \text{Total market demand}))$$

State Variables

The state variables that have effect on the final outcomes of the alternatives are listed below. Their units of measurement are also specified.

- Total market demand (billion dollars)
- Market share (million dollars)
- Fixed cost (million dollars)
- Variable cost (million dollars)
- Pilot investment result (success or failure)

- Expansion investment (without pilot investment) result (success or failure)
- Expansion investment (with pilot investment) result (success or failure)

Value Model

The relationships among the state variables leading to nine different statuses are described in Table 1.

Pilot Investment	Market share (%)	Fixed cost (%)	Variable cost (%)	Expansion Investment	Market share (%)	Fixed cost (%)	Variable cost (%)
Success p=.9	0	2	-2	Success p=0.8	50	100	-10
				Failure p=.9	-5	80	-5
				No Invest	-5	0	0
Failure p=.1	0	2	0	Success p=0.8	50	100	-5
				Failure p=0.2	-5	80	0
				No Invest	-5	0	0
No Invest	0	0	0	Success p=0.7	50	100	-5
				Failure p=0.3	-5	80	0
				No Invest	0	0	0

Table 1. Summary of Cash Flow Impacts (Balasubramanian et al., 2000)

Decision Diagram

Figure 1 is a graphical representation of the decision model described above in the form of a decision diagram. The rectangle nodes represent decision variables (i.e., alternatives here). The oval nodes are chance nodes (i.e., state variables here). An arc from a chance node to a decision node indicates that the value of the chance node will be known when that decision is made. The diamond node is the value node that represents the value function of the decision maker. An arc from a chance or decision node to a value node signifies the effect of that variable on the value function. An arc from one chance node to the other chance node represents the possibility that the successor node is conditional on the originating chance node. The absence of such an arc means the chance nodes are irrelevant (Howard, 1990; Howard & Matheson, 1984).

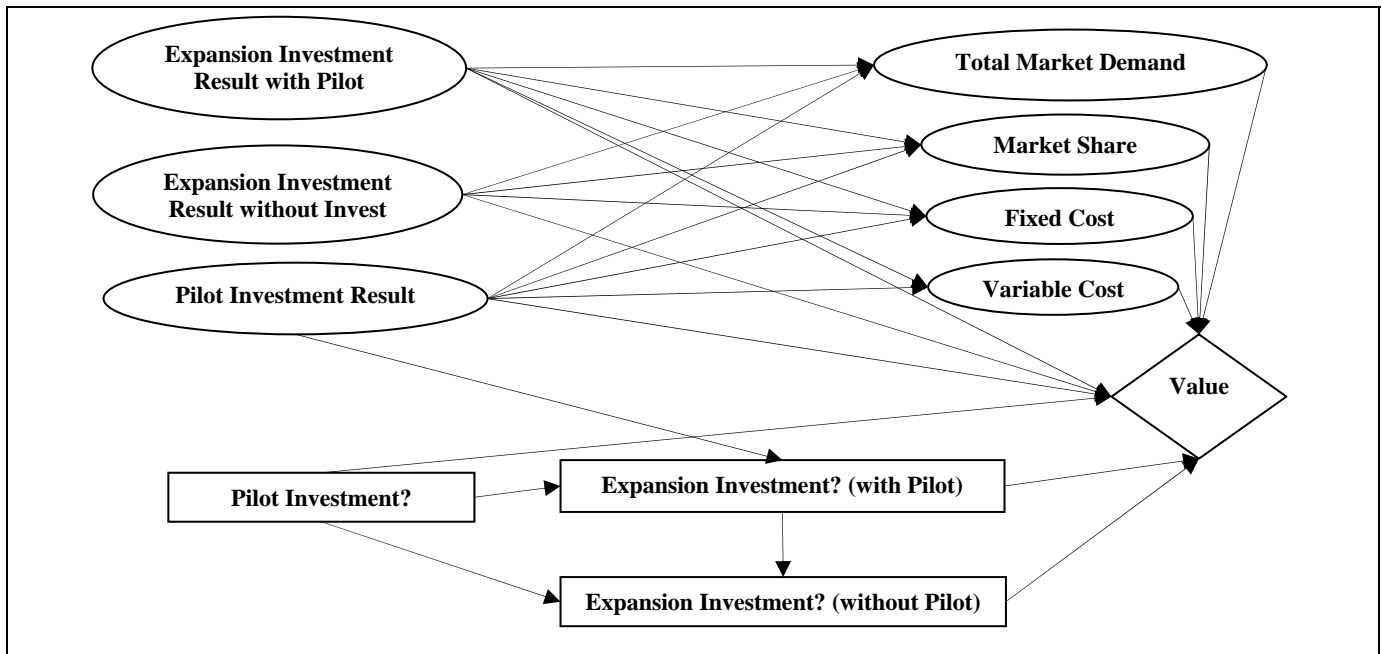


Figure 1. Decision Diagram

Generic Decision Tree

Figure 2 is the decision tree of NMT imaging system investment decision model.

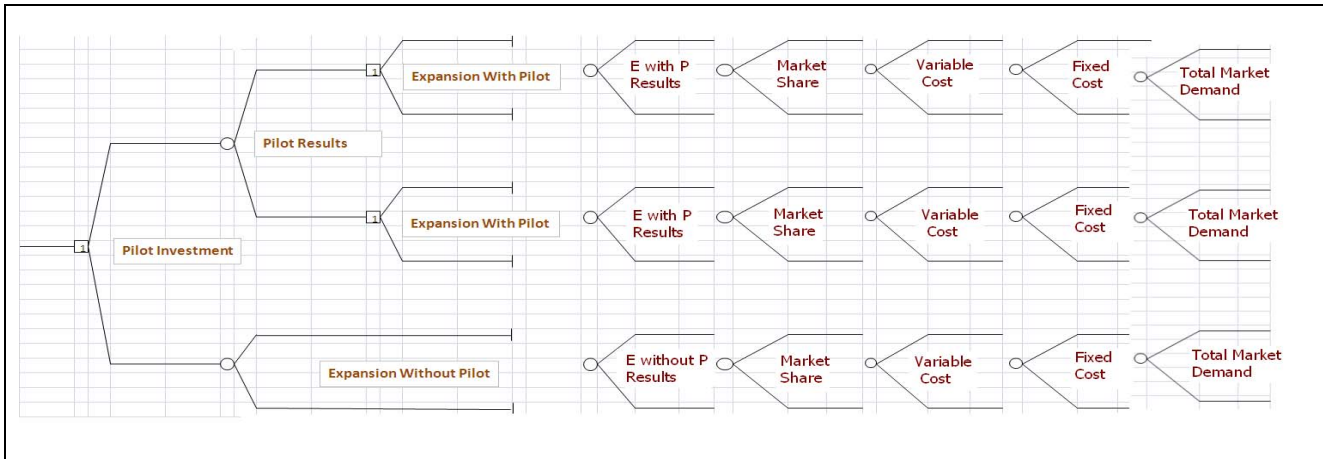


Figure 2. Generic Decision Tree

Deterministic Sensitivity Analysis

Once the decision description is specified the deterministic sensitivity analysis can be conducted. Deterministic sensitivity analysis identifies state variables and alternatives that worth probabilistic analysis. In this analysis, the nominal value and the range of possible values each state variable may take is determined. Then, the outcome value for each alternative are calculated, while all variables (except one of them) are set at their nominal values. The remaining variable is given its low and high values once at a time. This will be repeated for all the state variables. The results represent the sensitivity of each alternative outcome to each state variable. A wide range of outcome values over different values of a state variable shows the major effect of that variable on alternative outcomes. These variable called aleatory variables are worthy for probabilistic analysis. Tornado diagrams illustrate the result of deterministic sensitivity analysis.

It is possible to observe that an alternative outcome is always superior to another for all the different values in the range of state variables. In that case, the first alternative is said to deterministically dominate the other alternative. Deterministic dominance principle usually allows reducing the decision model by eliminating the dominated alternative. It is not practical to calculate the alternative outcomes for all possible state variable values. Hence, deterministic dominance is often approximated by tornado dominance. A tornado dominance of one alternative is recognizable over another alternative, if the former is always on the right of the latter in the relevant tornado diagram (Howard, 1966; Howard, 2007).

Table 2 shows the state variables and their low, high, and nominal values used in the present study. As combined tornado diagram (Figure 3) depicts, all the nine statuses (see Table 2) are overlapped. Therefore, there is no determinist dominance among them. In addition, aleatory variables (those with wider horizontal bars) are market share and variable cost. Hence, the other variables values (i.e., total market demand and fixed cost) are fixed at their nominal values for the rest of decision analysis cycle. The rest of the variables are not continuous and their effects were evaluated in each of the nine separate statuses. The reduced decision model containing the aleatory variables and the alternatives appropriate for next phase of analysis is shown in Figure 4.

Variables	Low	Nominal	High
Total Market Demand	74	75	76
Market Share	290	513	825
Variable Cost	200	300	500
Fixed cost	80	90	110

Table 2. Values for Sensitivity Analysis

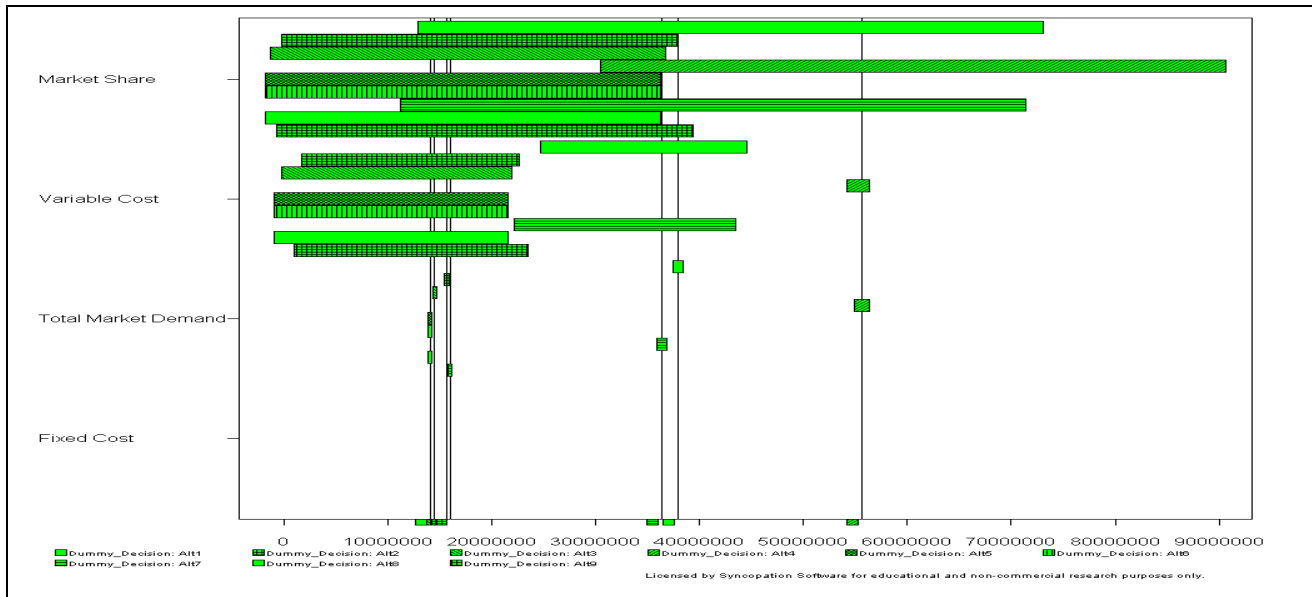


Figure 3. Combined Tornado Diagram

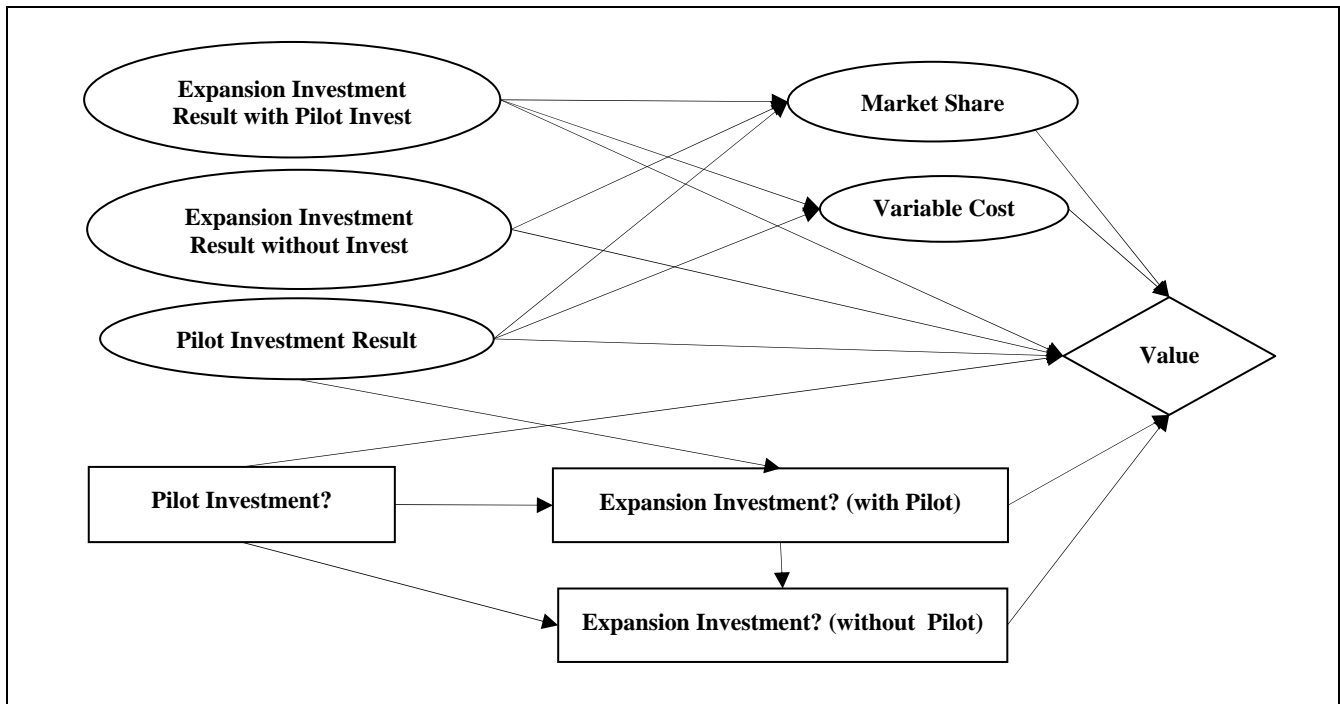


Figure 4. Reduced Model

Probabilistic Phase

Probabilistic phase (Howard, 1966, 1968) deals with the uncertainty in the aleatory variables and the decision maker’s risk preference. In this phase probability distribution of aleatory variables is encoded. For independent variables, a single probability distribution is required. For dependent variables, both conditional and marginal probability distribution is needed.

The interpretation of probability in decision analysis is subjective. In this subjective view, the probability represents a subjective measure of the state of knowledge about a phenomenon rather than being a dispositional property of it. Hence, in probability encoding process, the decision maker or any knowledgeable person who s/he identifies will assign probabilities to

aleatory variables. The details on this subjective probability assignment process is discussed in (Spetzler & Stael von Holstein, 1980)

The next step is to drive the risk profile associated with each alternative, and identify the best course of action using the stochastic dominance concept. Risk profile is a graph that shows the probabilities associated with all the possible outcomes of an alternative. It describes the relative riskiness of alternatives. If two cumulative risk profiles (A and B) are such that no part of profile A lies to the left of the profile B, and at least some of it lies to the right of B, then the alternative corresponding to profile A statistically dominates the alternative for profile B and is preferred to it (Clemen & Reilly, 2001).

When the stochastic dominance is not observed, in order to identify the best decision, the decision maker’s risk preference (in a utility function form) should be encoded. The risk preference will determine whether or not the decision maker would prefer a 5 million dollars profit for sure to equal chances of earning zero or 12 million dollars profit. Details of the risk preference encoding process is discussed in Howard (1984)

Once the utility function is calculated, the best decision will be the alternative with highest expected utility. In addition, stochastic sensitivity analysis can also be conducted to identify the sensitivity of the best decision to a particular aleatory variable while other variables are also uncertain. The results help to identify the robustness of the best determined decision, whether the aleatory variables determined in previous analysis are really crucial, and whether more precise information encoding about aleatory variables is needed to enhance the decision quality (Howard, 1968).

Since data of this study is secondary, it is assumed that total market demand for mortgage follows a lognormal distribution with the standard deviation and mean of 0.35 and 75. The cumulative probability distribution used for variable cost is also shown in Figure 5.

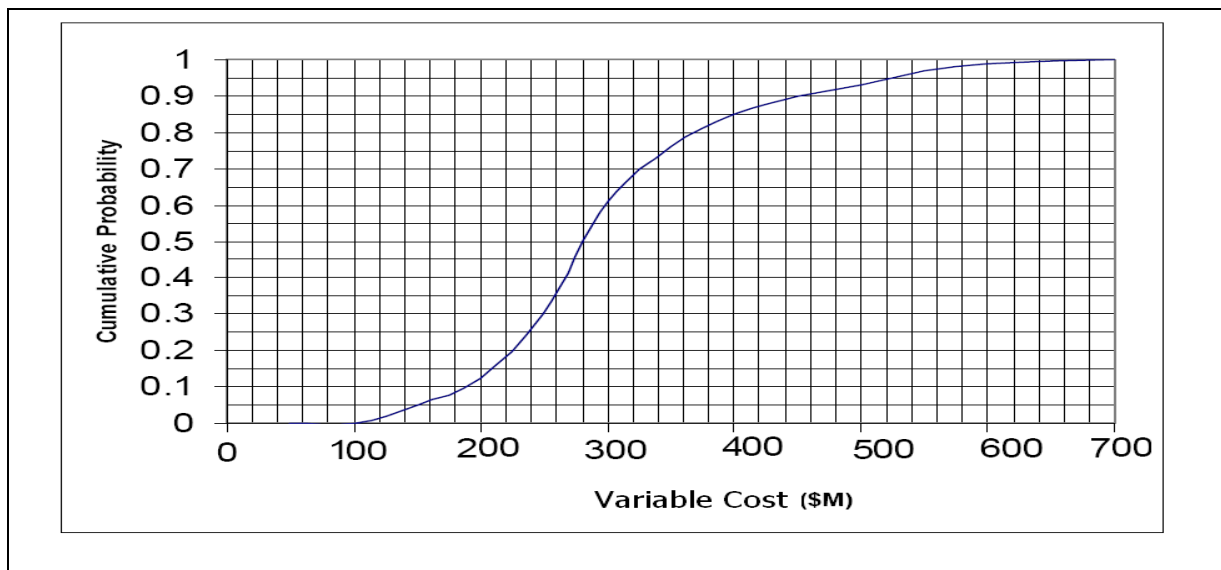


Figure 5. Cumulative Probability Distribution of Variable Cost

Based on these probability assignments, the following risk profile is derived for the alternatives (Figure 6). According to this risk profile no first order stochastic dominance exists.

Assuming that the decision maker is risk neutral, further analysis is conducted to find the best course of action. Optimal decision policy based on the above probabilities, preference, and values is all-around implementation of the imaging system from the beginning, without a pilot implementation (Figure 7).

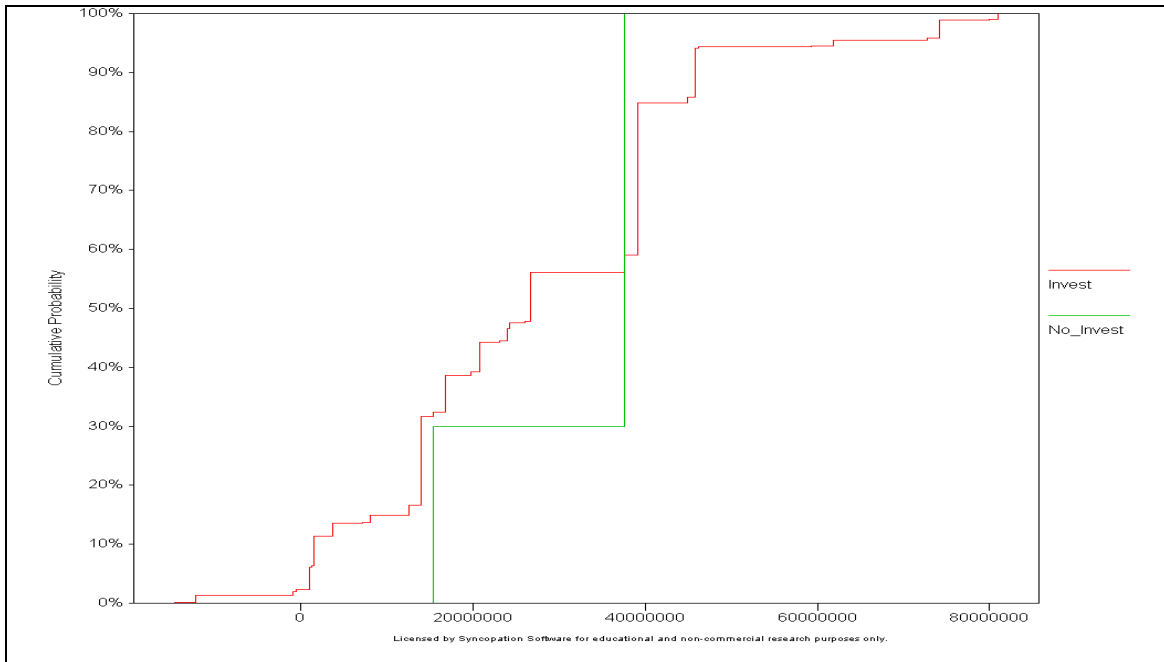


Figure 6. Stochastic Analysis

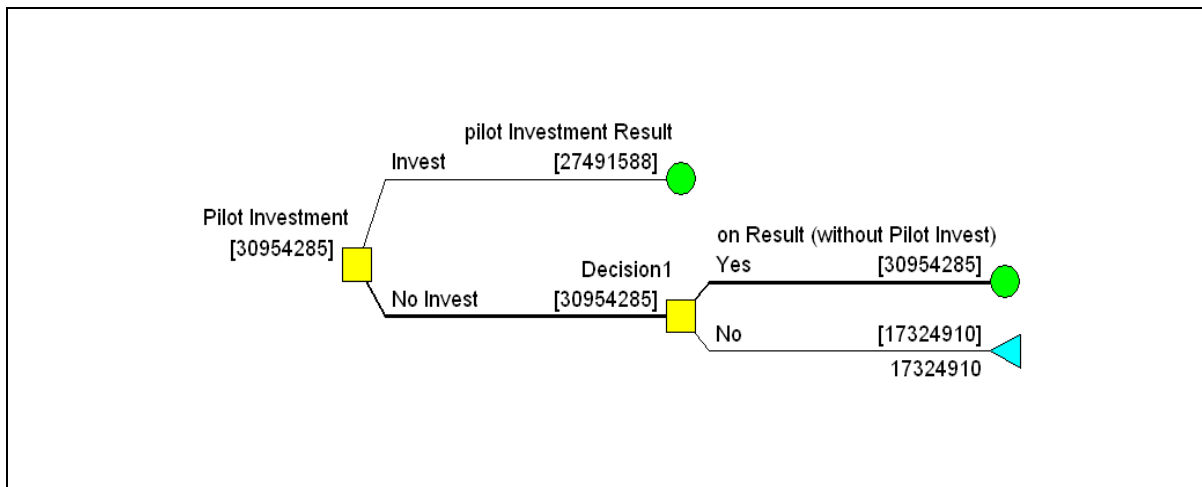


Figure 7. Optimal Decision

Information Phase

Information phase deals with the determination of economic value associated with the reduction or elimination of uncertainty in the state variables individually or jointly. The results identifies if collection of additional information (e.g., by market scanning) on each or all of the state variables is economically worthy. If any additional information is obtained, then it will be embedded in the new decision model and decision analysis cycle will be repeated from probabilistic phase. Without further information, the cycle terminates by determining the best course of action according to the available information. (Howard, 1966; Matheson & Howard, 1984)

Clairvoyant is a key concept in information value analysis.” The clairvoyant is an individual who can tell us the precise value of any uncertain variable.” (Howard, 1968, p. 217) However, this information is not free of charge. The value of clairvoyance or expected value of perfect information on an uncertain variable is the cost of clairvoyance at which the decision maker is just indifferent between buying and not buying the information. This value represents the maximum amount the decision maker should be willing to pay for the perfect information. This amount offers a criterion to assess any

information gathering plan. If the cost of the plan exceeds the value of clairvoyance, there is no need to consider it (Howard, 1968). The details on the clairvoyance value calculation are available in Howard (1984).

The expected values of perfect information (EVPI) on each of the state variables in NMT decision problem and their joint-EVPI are calculated using DPL. They are listed below and illustrated in Figure 8.

- EVPI on Market share = 34789282 million\$
- EVPI on Expansion result without pilot investment =34581413 million\$
- EVPI on Variable cost =31865582 million\$
- EVPI on Expansion result with pilot investment =31378461 million\$
- EVPI on Pilot investment result =0 million\$
- Joint-EVPI on = 27491588-30954285=-3462697 million\$

Based on the above EVPIs, information gathering on market share has the highest clairvoyance value, and the joint-EVPI is not economic (negative clairvoyance value).

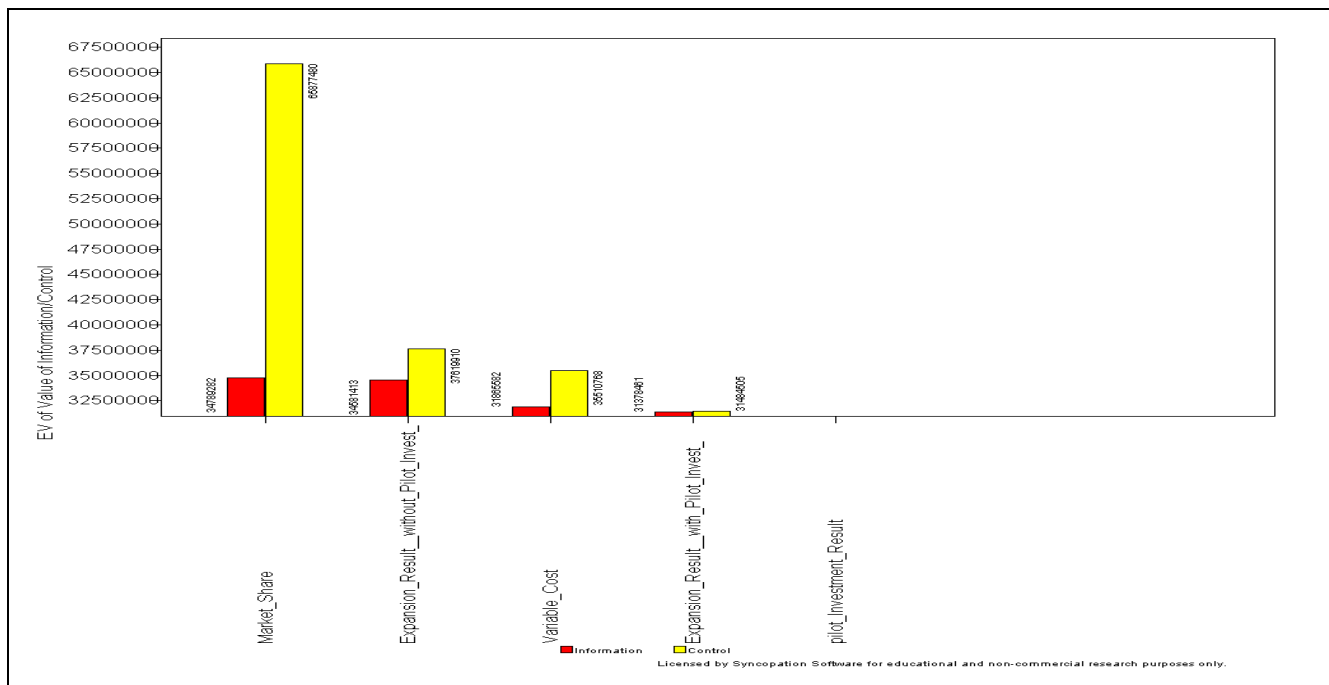


Figure 8. EVPI's

RESULT

A decision analysis cycle was conducted on the NMT imaging system investment decision problem. The decision model was specified in deterministic phase, and market share and variable cost were identified as aleatory variable. The results of probability analysis after taking into account the uncertainty in aleatory variables and a risk neutral preference, indicated that the best strategy for NMT in this investment decision is not to engage in pilot statement and directly invest on an around implementation of the system to all offices. However, the identification of this alternative as the best course of action may sounds odd, because pilot investments are always helpful benchmarks of the investment success. The point is that the one step all-around implementation is selected in decision analysis cycle, while the analysis has already taken into the account all the different uncertainties and risks of the possible alternatives and state variables. The 10% increase in the possibility of failure in all-around implementation alternative compared to having a pilot implementation is one example of such consideration.

CONCLUSION

The decision analysis cycle and its three phases are explained in details. The application of the cycle to an IT investment decision in this study indicates that this methodology can be a useful framework to account for complexity, uncertainty and risk in IT investments. IT helps to systematically describe the decision problem, capture the connection between various possible alternatives, their outcomes, and variables that influence the outcomes value. It refines the decision model progressively in deterministic, probabilistic and economic contexts, and finally determines the best course of action based on the available information. The cycle can be repeated by gaining more information when it is economical and enhance the decision quality to the desired degree.

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