An Examination of IT Initiative Portfolio Characteristics and Investment Allocation: A Computational Modeling and Simulation Approach

Completed Research Paper

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ABSTRACT

We advance the theory pertaining to IT governance and portfolio management. We specifically examine how the portfolio characteristics can influence IT investment allocation. We propose two portfolio characteristics – flexibility and diversity. We define the flexibility as the number of IT investment choice, and the diversity as the dissimilarity of IT investment choice. Using the Monte Carlo simulation and real-world data, we find that 1) if a firm invests in a set of IT initiatives with higher flexibility, it will have greater potentiality to capture a superior IT investment allocation; 2) when a firm invests in a set of IT initiatives with lower flexibility, it will have greater potentiality to capture a superior IT investment allocation, if the set of IT initiatives involves higher diversity. Our findings implicate that a firm can exercise IT initiative flexibility and diversify IT initiative choice to improve portfolio investment allocation.

Keywords

IT portfolio, IT investment, IT governance

INTRODUCTION

It is widely established that the performance of IT investment can vary significantly across firms. In this paper, we propose one important explanation for such variations in performance — the portfolio characteristics. From our observation in practice, we notice considerable variations in sets of IT initiatives across firms. If we view a set of IT initiatives as a portfolio and regard it as a target for a firm’s IT investment allocation, we expect that the portfolio characteristic would make a great impact on a firm’s IT investment allocation, which in turn would directly influence a firm’s IT investment performance.

In this paper, we specifically examine how the portfolio characteristics can influence IT investment allocation. We propose two portfolio characteristics – flexibility and diversity. In our definition, flexibility refers to the number of IT investment choice, and diversify refers to the dissimilarity of IT investment choice. We equate the IT investment allocation with the quality of the optimal IT investment choice. We then design and develop a decision support model that aims to select a best set of IT initiatives as a firm’s optimal IT investment choice, according to a firm’s IT investment risk limit and budget limit. Moreover, we differentiate between different flexibility degrees by simulating sets of divisible/indivisible IT initiatives for IT investment decision, and differentiate between different diversity degrees by simulating high/low dispersion degrees (σ) for sets of IT initiatives’ values, risks, and costs in the distribution.

We use the simulated data combined with the real-world data. At first, we collect a data set of IT initiatives from two business units of a leading company in insurance and finance industry. Next, we use the collected data set to calibrate the variation degree of the simulated data. Specifically, we take the mathematical moments (i.e., mean and standard deviation) of the real-world data and feed them to the Monte Carlo simulation to propagate large sets of data on the basis of the Gaussian distribution.

Our experiment results show that if a firm invests in a set of IT initiatives with higher flexibility, it will have greater potentiality to capture a superior IT investment allocation. Moreover, once if a firm invests in a set of IT initiatives with lower flexibility, it still can have greater potentiality to capture a superior IT investment allocation, as long as the set of IT initiatives involve higher diversity. In other words, our findings implicate that a firm should exercise the managerial
flexibility embedded in its IT initiatives and diversify its IT initiative choice in order to increase its IT investment allocation efficiency and improve performance.

We organize the remainder of this paper as follows. In section 2, we define the portfolio characteristics followed by our propositions. In section 3, we outline the development of our IT portfolio decision support model. In section 4, we describe our method, experiment design, and data collection. In section 5, we summarize our results and findings. In section 6, we discuss the managerial implications. In section 7, we conclude this paper with contributions.

PROPOSITIONS AND RELATED LITERATURE

The Flexibility Characteristic of an IT Initiative Portfolio

In this paper, we define the flexibility as the number of choices that a firm can select from its set of IT initiatives to decide its IT investment. In prior related literature, managerial flexibility is regarded as one critical role in a firm’s resource allocation strategy (Trigeorgis, 1996). In economics, resource means any asset a firm can purchase, lease, or produce for its own use, such as labor, land, etc. In a firm, the completion of an IT initiative also requires the asset including skill, facility, etc. which is generated from a combination of the economic resources. In addition, the resource allocation of an IT initiative is determined by a firm’s IT investment decision. Therefore, we reason that if a firm can have a plenty of investment choices, it will have higher flexibility to allocate its IT investment, according to its strategic plan. In turn, this firm will have more potentialities to better capitalize valuable opportunities or mitigate potential losses, contributing to a better investment performance.

Moreover, we view each IT initiative as an investment target in a firm. An IT initiative is served as an umbrella to cover the associated IT projects for the same strategic objectives as well as investment purposes. In this paper, an IT initiative specifically refers to an IT−dependent strategic initiative (Piccoli and Ives, 2005). Moreover, such an initiative is defined as having the identifiable objectives that leads to sustained improvements or limits the erosions of a firm’s competitive advantage. For example, an IT initiative can include building the information systems or applications, such as ERP, CRM, etc., to generate competitive advantage; these systems are often complicated to develop and malleable to change, making the competitive imitation slow, difficult, and costly. In other words, an IT initiative is dependent on the IT projects, since it cannot be implemented until necessary and associated information systems have been successfully deployed.

Not every IT initiative can provide many investment choices. In practice, we observe that there are two types of IT initiatives. One type is flexible and the other is inflexible. In particular, the two types of IT initiatives will provide very different numbers of IT investment choices. In a firm, most financial investments are very flexible and able to provide many choices. Hence, for example, a firm can consider choices of increasing the amount of a stock investment to capture greater investment return, or decreasing it in order to alleviate the potential investment loss. To IT investment, however, many IT initiatives can only provide few investment choices. For example, if an IT initiative is proposed to develop an innovative CRM system, a firm perhaps cannot have any choice, but one full investment choice, in order to capture investment return. This is primarily because such an investment is not very flexible, and any return can hardly be realized until the entire initiative is completed.

On the other hand, if an IT initiative is proposed for acquiring a Cloud-based CRM, the investment in that IT initiative can be very flexible. One important feature of cloud computing is the price elasticity (e.g., pay-as-you-go). This implies that such an investment can provide many choices based on a firm’s demands. Moreover, certain web initiatives (e.g., website development) can also provide many investment choices, since they are able to be divided into cycles and thus benefit from the completion of early cycles. Therefore, we derive a proposition as follows.

**Proposition 1:** If a firm invests in a set of IT initiatives with higher flexibility, it will have greater potentiality to capture a superior IT investment allocation.

The diversity Characteristic of an IT Initiative Portfolio

We now turn to investigating the IT investment allocation strategy when a firm has to invest in a set of IT initiatives with lower flexibility. In corporate economics, diversification refers to the degree to which a firm is able to operate in lines of business. It is suggested that a rent-seeking firm can diversify and thus benefit from allocating its excessive economic resource more efficiently. For example, a firm can increase the diversity of its products and benefit from the economy of scope. Most importantly, the rationale behind such a diversification strategy relies on a precondition - the resource is not very
flexible for use. For example, Penrose (1959) indicate that the indivisibility of resources preclude a firm from finding the best way to use resource and thus attain at a “state of rest” (i.e., an equilibrium position where a firm can hardly use its resources more profitably). Further, Teece (1980) maintains that the resource indivisibility alone can seldom result in the resource use difficulty postulated by Penrose, unless there is a friction for the resource external transfer. For example, if the resource has high liquidity and thus marketable, a firm can just sell the unused resource to the market. In such a situation, the link between a firm’s diversification strategy and the resource indivisibility can seldom sustain. In short, corporate economic strategists argue that diversification is helpful to overcoming the resource allocation challenges posed by the resource lacking divisibility and liquidity.

In this paper, we define the diversity as the dissimilarity of choices that a firm can select from its set of IT initiatives to decide its IT investment portfolio. From a decision-making viewpoint, choice diversity implicates there are more opportunities to capture a better decision. According to the classical utility theory, the similarity between a pair of goods is contingent on the marginal utility associated with a set of goods consumed. In other word, the dissimilarity between two goods can be viewed as the degree to which the two goods are not substitutable (Nehring and Puppe, 2002). Thus, if we view the goods as IT initiatives, we can reason that a set of more diversified IT initiatives can provide more non-substitutable choices, and thus we can have a broader search range for a better decision. In addition, we observe that certain IT initiatives are indivisible and cannot be sold to the market. Thus, if we regard an IT initiative as the resource from the view of Penrose and Teece, we reason that we should be able to apply the analogous diversification idea to improving a firm’s IT investment allocation and decision making.

Not every two IT initiatives can present the same investment attributes, such as same cost, same return, etc. As a result, any two sets of IT initiatives for a firm’s investment consideration will involve different diversity degrees. For example, one common way adopted by many firms to classify IT initiatives is to use the class of run-the-business, grow-the-business, and transform-the-business. In a way, they respectively correspond to the class of low return/risk, medium return/risk, and high return/risk by the financial investment classification. In prior IS literature, Weill and Aral (2006) also proposes an IT asset classification framework including transactional, informational/strategic, and infrastructure classes, which also implicate that a set of IT initiatives can be differentiated by their dissimilarities. As a result, if a firm selects a set of IT initiatives primarily from only single class, we can expect its IT investment choice diversity naturally will be lower than the choice diversify when a firm selects a set of IT initiatives from the three classes. Therefore, we derive a proposition as follows.

**Proposition 2:** When a firm invests in a set of IT initiatives with lower flexibility, it will have greater potentiality to capture a superior IT investment allocation, if the set of IT initiatives involves higher diversity.

**MODEL DESIGN AND DEVELOPMENT**

Our model aims to maximize the value of a set of selected IT initiatives, given the accepted IT investment risk and budget limits. In other words, our selection rationale is grounded on the portfolio return-risk balance and return-cost balance criteria. The cost \( C \), risk \( R \), and value \( V \) are the main decision components followed by the risk limit \( R_0 \) and the budget limit \( C_0 \). Accordingly, if \( P \) is a vector representing a set of selected IT initiatives, we can derive a conceptual model as follows.

\[
\text{Max } V(P) \quad (1)
\]

Subject to: \( R(P) \leq R_0 \quad (2) \)

\[
C(P) \leq C_0 \quad (3)
\]

(This model is for maximizing the value of a set of selected IT initiatives, given the accepted IT investment risk and budget limits)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_i )</td>
<td>IT initiative decision variable</td>
</tr>
<tr>
<td>( v_i )</td>
<td>The NPV of IT initiative i</td>
</tr>
</tbody>
</table>
The Metrics and modeling processes

For IT initiative cost estimation, we adopt an integrated approach. This integrated cost will include the programming costs, hardware/software costs, and management costs. Accordingly, the total cost of a set of selected IT initiatives is as follows:

\[ C(P) = \sum_{i=1}^{n} c_i x_i \]  \hspace{1cm} (4)

For IT initiative risk estimation, we use an integrated risk scoring approach. This integrated risk will include the economic risk factor (e.g., size, resource limits, etc.), the organizational risk factor (e.g., procedure change, organizational management change, etc.), and technological risk factor (e.g., lack of expertise, technology convexity, etc.) (McFarlan, 1982; Wallace and Keil, 2004). Thus, the total risk of a set of selected IT initiatives is as follows:

\[ R(P) = \sum_{i=1}^{n} r_i x_i \]  \hspace{1cm} (5)

Regarding IT imitative value evaluation, we apply a financial modeling approach - NPV. In prior IT portfolio related literature, the financial value is one most important value considered in a firm’s investment decision (Kumar et al., 2008). Hence, the total value of a set of selected IT initiatives is as follows:

\[ V(P) = \sum_{i=1}^{n} v_i x_i \]  \hspace{1cm} (6)

As a result, by considering functions (4)(5)(6), we can derive a complete model as follows:\footnote{A use example is provided in appendix A}.

\[ \text{Max } V(P) = \sum_{i=1}^{n} v_i x_i \]  \hspace{1cm} (7)

Subject to: \[ R(P) = \sum_{i=1}^{n} r_i x_i \leq R_0 \]  \hspace{1cm} (8)

\[ C(P) = \sum_{i=1}^{n} c_i x_i \leq C_0 \]  \hspace{1cm} (9)

\begin{tabular}{ | l | l | }
  \hline
  \textbf{Notation} & \textbf{Description} \\
  \hline
  \textit{c}_i & The cost of IT initiative \textit{i} \\
  \textit{r}_i & The risk score of IT initiative \textit{i} \\
  \textit{C}_0 & The budget limit for the selected set of IT initiatives \\
  \textit{R}_0 & The risk limit for the selected set of IT initiatives \\
  \textit{P} & A vector representing a set of selected IT initiatives \\
  \hline
\end{tabular}

\textbf{Definitions of Mathematical Notation in the Model}
METHOD

In this paper, we employ an integrated research method that incorporates computational modeling and data simulation. In prior IS literature, the computational method is often adopted on the condition that the sufficient empirical evidence is too costly to collect (Green et al., 2010; Nan, 2011; Piramuthu and Shaw, 1998; Sikora and Shaw, 1988; Tu et al., 2009). In addition, we use a certain amount of real-world IT initiative data to initialize the simulation, so that we can make our results more reliable and more grounded in practice.

The experiment design

In this paper, we seek to explore how the two portfolio characteristics – flexibility and diversity can influence IT investment allocation. We design two computational experiments for examining our two propositions. In experiment 1, we aim to observe whether a set of IT initiatives with high/low flexibility will influence the frequency of generating an optimal and superior portfolio choice from the proposed model (i.e. a choice of maximizing portfolio value, given accepted risk and cost). We design two scenarios. In scenario 1, we assume that a set of IT initiatives is composed of a set of divisible IT projects, which refers to a set of IT initiatives with high flexibility. In scenario 2, we assume that a set of IT initiatives is composed of a set of indivisible IT projects, which refers to a set of IT initiatives with low flexibility. Accordingly, in the scenario 1, we set the real value for the decision variable \( x \), and in scenario 2 we set the binary value for it. In experiment 2, we will observe whether a set of inflexible IT initiatives with high/low diversity will influence the frequency of generating an optimal portfolio choice from the proposed model. We use three scenarios to reflect three diversity degrees, 1) the less-diversified, 2) the medium-diversified, and 3) the more-diversified scenario. We operationalize the diversity degree by varying the dispersion degrees \( \sigma \) of IT initiative value, risk and cost in the distribution.

Moreover, we use the value/risk ratio to decide the superiority of IT investment allocation. This ratio is analogous to the sharp ratio (Sharpe 1994), which is a common portfolio performance index in finance. First, we define a threshold ratio, the ratio of the original set of IT initiatives before selection. Next, we compute the ratio of the optimal IT investment choice selected by the proposed optimization model. Finally, only if the ratio of the optimal choice is greater than that of the threshold ratio, we count it as a superior IT investment allocation. Besides, we use different budget considerations and potential risk tolerance levels. First, we randomly set the budget limits. A portfolio choice will be considered only if its total cost is under the budget. Second, we assume that a firm will tend to govern its IT investment risk and thus we simulate a firm’s potential accepted risk levels as high, medium, and low. If a firm’s accepted risk for its IT investment is low, any portfolio choice whose risk is greater than the 25% of the maximum possible portfolio risk will not be taken as superior; if a firm’s accepted risk for its IT investment is medium, any portfolio choice whose risk is greater than the 50% of the maximum possible portfolio risk will still not be taken as superior; even if a firm’s accepted risk for its IT investment is high, any portfolio choice whose risk is greater than the 75% of the maximum possible portfolio risk will still not be taken as superior.

Data collection

For experiment input, we use the simulated data combined with the real-world data. At first, we collect a data set of IT initiatives from the business units of a leading company in insurance and finance industry. Each IT initiative includes value, risk, and cost information; the value information is estimated by the company’s financial experts, and risk and cost information are estimated by the manager of the business unit that proposes the IT initiative for a strategic purpose. This company also has an MIS unit for supporting the company’s general IS/IT functions. Next, we use the collected data set to calibrate the variation degree of the simulated IT initiatives. Specifically, we calculate the mathematical moments (i.e., mean and standard deviation) of the IT initiatives and feed them to the Monte Carlo simulation to propagate data, according to the normal distribution (Gaussian distribution). We use a personal computer (Intel Duo 2.8G CPU with 8GB RAM) to implement the simulation.

RESULT

The frequency of generating a superior IT investment choice for allocation in the experiment 1 and experiment 2 are shown in table 1 and table 2. We run 30 different data sets for each of the 10 iterations, and each set is composed of 30 IT initiatives.

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2 The details of diversity scenarios are listed in appendix B

3 The details of moments of real-world data are listed in appendix
In the bottom lines, we compute the overall average frequencies, their standard deviations in the parentheses, and the overall average frequency.

![Table 1. Superior IT Investment Choice Selection Frequency for Experiment 1 Result](image)

(Note: This result table is for examining our proposition 1: if a firm invests in a set of IT initiatives with higher flexibility, it will have greater potentiality to capture a superior IT investment allocation. The Low, Medium, and High accepted risks refer to a firm’s different possible accepted risks toward IT investment).

![Table 2. Superior IT Investment Choice Selection Frequency for Experiment 2 Result](image)

(Note: This result table is for examining our proposition 2: when a firm invests in a set of IT initiatives with lower flexibility, it will have greater potentiality to capture a superior IT investment allocation, if the set of IT initiatives involves higher diversity. The Low, Medium, and High accepted risks refer to a firm’s different possible accepted risks toward IT investment).
Summary of Findings

The experiment 1 results (table 1) support our proposition 1. We propose that if a firm invests in a set of IT initiatives with higher flexibility, it will have greater potentiality to capture a superior IT investment allocation. As seen in our summary of finding (figure 1), we can find that if a set of IT initiatives involve high flexibility, the frequency of capturing a superior IT investment choice will be clearly higher than the frequency when a set of IT initiatives involve low flexibility.

![Figure 1. Summary of Experiment Result 1](image)

The experiment 2 results (table 1) also support our proposition 2. We propose that when a firm invests in a set of IT initiatives with lower flexibility, it will have greater potentiality to capture a superior IT investment allocation, if the set of IT initiatives involves higher diversity. As seen in our summary of finding (figure 2), we can find that if a set of IT initiatives involve low flexibility but high diversity, the frequency of capturing a superior IT investment choice will be clearly higher than the frequency when a set of IT initiatives involve low flexibility and diversity.

![Figure 2. Summary of Experiment Result 2](image)

DISCUSSION

Exercising IT Initiative flexibility to improve portfolio investment allocation

From the corporate economic perspective, a firm’s value creation is critically contingent on both the strategy to allocate resources and the strategy to evaluate investment alternatives (Trigeorgis, 1996). In prior IS literature, there is a stream of studies investigating how to use the financial real-options approaches to evaluate the alternatives (options) of an IT investment (Benaroch and Kauffman, 2000; Fichman, 2004). One well-known example is that Benaroch and Kauffman (2000) apply the Black-Scholes model to reflect the underestimated investment value of a firm’s electronic banking network. In other words, the managerial flexibility concepts in these studies are directly linked to the options of generating additional
value (i.e., the future value) for an IT investment. In fact, as Trigeorgis (1996) argues, the managerial flexibility provided by an IT investment would bring to a firm another benefit, i.e., the improvement of investment resource allocation.

In this paper, our findings show that, in terms of IT investment allocation, a set of flexible IT initiatives is better than that of a set of inflexible IT initiatives. This implicates that a firm can consider exercising the managerial flexibility of de-investment/re-investment for certain IT initiatives to improve the overall IT investment allocation for a portfolio. Namely, our findings complement to the prior IS literature. Our findings reflect that the managerial flexibility of an IT investment is not only related to the future value for an IT investment but also relevant to the overall investment allocation for a portfolio of IT initiatives.

**Diversifying IT initiative choice to improve portfolio investment allocation**

For managing IT initiatives, the idea of diversification is not only helpful for reducing the risk, but also for allocating a firm’s investment more efficiently in a portfolio. In prior IS research, the financial portfolio theories, such as the modern portfolio theory (Markowitz, 1959) are often applied to addressing the issues related to IT portfolio management. From the perspectives of such theories, a firm should diversify investments in order to strike an average for mitigating the risk of investment, i.e., not putting all your eggs in one basket. Strictly speaking, this benefit of investment diversification is on the basis of a set of related investments that are characterized by the mutual interdependency. However, there is another situation where a set of investments could be unrelated and characterized by the pooled interdependency. For example, in corporate economics, it is often argued that a firm should seek for diversifying the unrelated lines of business in order to capture the benefits of resource allocation efficiency.

In this paper, our findings complement the prior IT portfolio studies and highlight the importance of diversifying unrelated IT investment. Our result 2 implicates that a diversified set of unrelated IT initiatives can generate a better portfolio investment allocation, since each IT initiative is mutually independent but share the similar pools of risk constraint and budget constraint in our experiments. More importantly, we provide an important reason why a firm needs to adopt a diversification strategy for a better portfolio performance, even if its IT initiatives have very low mutual interdependencies.

**CONCLUSION AND CONTRIBUTION**

This paper makes several contributions to research and practice. First, our portfolio-level findings, in terms of characterizing and managing of IT initiatives as a collective, can strongly complement the prior IS research focused on individual IT project and thus advance theories pertaining to IT governance and portfolio management. Second, our experimental results highlight that a firm can achieve better IT investment allocation by employing the managerial flexibility of IT initiative or diversifying the selection choice of IT initiative. Third, we create the decision model to support IT initiative portfolio decision-making. In the past, the primary decision model that firms could rely on was the financial portfolio models. Such models are often difficult to accommodate a firm’s IT investment context. A most obvious weakness, for example, is that the input metrics of the financial portfolio models rely on the financial asset’s historical price, which fails to translate to the common IT initiative management routines in a firm. Finally, we employ an integrated research methodology that incorporates computational modeling, real-world data, and simulations, which would strongly complement existing methodologies established in IS. In the future, we plan to investigate the characteristic-directed strategies for managing IT initiative portfolio and it is a research topic of great needs from both academic and business communities.

**REFERENCE**

APPENDIX A

This example is adapted from a real-world case. We demonstrate a small set of IT initiatives, and it is collected from a financial service unit of an insurance company in the Midwest during 2009-2010.

<table>
<thead>
<tr>
<th>Id</th>
<th>Initiative name</th>
<th>NPV</th>
<th>Risk</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1</td>
<td>J2EE platform migration</td>
<td>$80000</td>
<td>80</td>
<td>$1490000</td>
</tr>
<tr>
<td>x2</td>
<td>Mobile payment plan</td>
<td>$100000</td>
<td>50</td>
<td>$380000</td>
</tr>
<tr>
<td>x3</td>
<td>Contract management system upgrade</td>
<td>$40000</td>
<td>50</td>
<td>$460000</td>
</tr>
<tr>
<td>x4</td>
<td>Payroll system upgrade</td>
<td>$10000</td>
<td>15</td>
<td>$390000</td>
</tr>
<tr>
<td>x5</td>
<td>Underwriting system upgrade</td>
<td>$20000</td>
<td>5</td>
<td>$580000</td>
</tr>
<tr>
<td>x6</td>
<td>Life and auto policy web interface</td>
<td>$250000</td>
<td>40</td>
<td>$1080000</td>
</tr>
<tr>
<td>x7</td>
<td>Annuity policy modification</td>
<td>$220000</td>
<td>20</td>
<td>$90000</td>
</tr>
<tr>
<td>x8</td>
<td>Client e-notice system</td>
<td>$180000</td>
<td>20</td>
<td>$290000</td>
</tr>
<tr>
<td>x9</td>
<td>Partnership e-credit plan</td>
<td>$160000</td>
<td>50</td>
<td>$300000</td>
</tr>
<tr>
<td>x10</td>
<td>Electronic money transferring gateway</td>
<td>$60000</td>
<td>70</td>
<td>$820000</td>
</tr>
<tr>
<td>x11</td>
<td>Debt/lending data analysis plan (BI)</td>
<td>$70000</td>
<td>60</td>
<td>$1130000</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>$1190000</td>
<td>460</td>
<td>$7010000</td>
</tr>
</tbody>
</table>

Table 3. The IT Initiative Investment Data Table

In this example, we want to select two best sets of IT initiatives (an aggressive portfolio choice and a conservative portfolio choice for the company’s investment consideration; thus, the risk constraints ($R$) are set as 25% and 75% of the highest risk score (460). In addition, we want to cut into half the total cost of the investment, so the cost constraint ($C$) is set as 50% of the highest cost ($7010000). These settings just follow the heuristics, and the settings in different companies would be very contingent. Moreover, by using our proposed model (7)(8)(9), we can derive the following optimization problem.

Max $(x1*800000+x2*100000+…x11*700000)/1190000$  
(10)

s.t. $(x1*80+x2*50+…x11*60)/460\leq R$  
(11)

$(x1*1490000+x2*380000+…x11*1130000)/7010000\leq C$  
(12)

We then use an optimization software (LINDO) and a personal computer to solve (10)(11)(12) and derive the two best sets of IT initiatives for a company’s aggressive portfolio choice and conservative portfolio choices as follows.

<table>
<thead>
<tr>
<th>Portfolio choice</th>
<th>Selected IT initiatives</th>
<th>NPV</th>
<th>Risk</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservative</td>
<td>{x5,x6,x7,x8}</td>
<td>$670000</td>
<td>85</td>
<td>$2040000</td>
</tr>
<tr>
<td>Aggressive</td>
<td>{x1,x2,x4,x5,x6,x7,x8,x9,x10}</td>
<td>$1080000</td>
<td>350</td>
<td>$3420000</td>
</tr>
</tbody>
</table>

Table 4. The IT Initiative Portfolio Choice Results

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The risk is estimated by using a scoring approach (1-100). The lowest value on this spectrum – 1 – indicates the initiative is very low risk. The highest value on this spectrum – 100 – indicates the initiative is very risky; such scores should be reflective of the initiative risk from a holistic investment perspective (i.e., inclusive of the business, IT, etc. perspectives)
APPENDIX B

<table>
<thead>
<tr>
<th></th>
<th>Value ($)</th>
<th>Cost ($)</th>
<th>Risk (score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(µ, σ)</td>
<td>(2000000, 2600000)</td>
<td>(2000000, 200000)</td>
<td>(50, 30)</td>
</tr>
<tr>
<td>min to max</td>
<td>60000-10000000</td>
<td>0-10000000</td>
<td>0 - 100</td>
</tr>
</tbody>
</table>

Table 5. Statistical descriptions of real-world data

High-Diversity: {Value ~N(µ, σ²)= (2000000, 2600000*2600000*3), Cost ~N(µ, σ²)=(200000, 200000*3), Risk score ~N(µ, σ²)=(50, 30*30*3)}

Low-Diversity: {Value ~N(µ, σ²)= (20000000, 26000000*2600000*0.33), Cost ~N(µ, σ²)=(2000000, 200000*200000*0.33), Risk ~N(µ, σ²)=(50, 30*30*0.33)}

Table 6. The diversity scenarios