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ABSTRACT

This paper provides a methodological framework in which the problem of IT project portfolio selection is solved by balancing between operational and strategic IT investments. From interviews with CIOs, we found that the interest in IT projects in many firms tends to center on operational benefits, rather than strategic benefits. We examined the impact of strategic IT investments from an IT portfolio perspective. We applied an optimization model for the IT the portfolio selection and developed a computational method to explore the impact of strategic IT investments. We found that, based on a long-term evaluation, IT portfolio selection focusing on both the operational value and the strategic value resulted in greater performance than IT portfolio selection focusing on the operational value alone. In addition, we found that the risk level of the strategic value of IT did not significantly affect the outcome of the IT portfolio in a strategic IT investment.

Keywords

IT portfolio selection, IT projects, strategic IT investments, strategic alignment of IT

INTRODUCTION

Balancing return and risk is one of the most essential decisions in selecting a portfolio in any investment. According to Markowitz's portfolio selection theory (Markowitz, 1952), investors select a financial portfolio on the efficient frontier, which is defined as a set of portfolios yielding maximized return, given a specific level of risks. In the context of information technology (IT) investments, we associate the problem of balancing return and risk with the problem of balancing the operational value and the strategic value of IT projects.

Benefits of IT projects can be achieved in various dimensions. From interviews with IT managers in three US Fortune 500 companies, we found that IT projects are evaluated in terms of multiple attributes of the expected benefit, and these attributes can be categorized into mainly two classes: the operational value and the strategic value. Two of the three firms we interviewed evaluated proposed or proceeding projects with their operational value and strategic value, whereas one firm classified IT projects into an operational project group and a strategic project group. Our study applies the setting of the first two firms, in which the value of individual IT projects comprised the operational value and the strategic value, because these appear to be consistent even with the IT project setting of the third firm. Projects in the operational project group can be interpreted as projects for which the operational value is much greater than the strategic value, and vice versa, whereas projects in the strategic project group can be defined as projects for which the strategic value is much greater than the operational value.

Our research questions were as follows: How do CIOs achieve the optimal IT portfolio, balancing the operational value and the strategic value? Does investment in the strategic value of IT enable the firm to increase its payoff of IT investments? If so, under what conditions are strategic IT investments significant for a better payoff? The purpose of our study was to provide a framework that would help firms conduct a strategic analysis of their enterprise IT investments. In particular, we analyzed the impact of strategic IT investments versus operational IT investments from the perspective of the CIO. This research may provide a foundation for creating a decision support system that would enable IT managers to optimize their IT portfolio.

THEORETICAL BACKGROUND

IT Project Selection and the IT Portfolio

Our study focuses on the managerial problem of selecting IT projects. IT project selection has emerged as a research topic because the size and scope of IT investments in firms have become increasingly significant. IT use in firms has become more diversified, and IT now plays more critical roles in business functions. Unlike in the past, a firm's IT spending is now large enough to view as a portfolio and for IT projects in a firm to be managed as a portfolio. In the early 1980s, McFarlan (1981) used the concept of the IT portfolio in proposing a quantitative method to manage IT risk. However, it is only quite recently that this concept has again been increasingly discussed in IT research. Maizlish and Handler (2005) and Kaplan (2005) have reinterpreted the IT issues of a firm from the point of view of a portfolio and have provided a comprehensive description of the IT portfolio.

Several methodologies for selecting IT projects have been proposed. Lucas and Moore (1976) discussed an IT project selection methodology based on a scoring model. Bacon (1992) and Santhanana and Kyparisis (1995) discussed multiple criteria in the problem of information systems (IS) project selection. Lee and Kim (2000) developed an IT project selection methodology using an analytic network process, within a zero–one goal programming model. Dickison et al. (2001) and Santhanana and Kyparisis (1996) emphasized the interdependency of technology projects and proposed a model for IT portfolio optimization using a dependency matrix. Verhoef (2002) proposed quantitative methods to manage the IT portfolio and described various IT problems in mathematical ways. Lin and Hsieh (2004) used fuzzy theory in their model of IT portfolio selection.

Weill (1990) conducted empirical studies to examine the impact of strategic IT investments. Of the possible categories, our study was based on Weill's (1990) view of IT investments because we found that many companies have the decision-making problem of balancing investments between operational IT and strategic IT. From the interviews with IT managers, we found that two approaches are used in evaluating IT projects: one approach is to score multiple values for individual projects, which can be categorized into operational values and strategic values, and the other approach is to categorize IT projects into an operational project group and a strategic project group. Two of the three firms used the former approach, and the other firm used the latter approach. In our study, we extended the first approach and assumed that the value of individual IT projects comprises the operational value and the strategic value. These two value attributes were considered as independent factors when firms select their IT portfolio from among proposed projects. The operational value of IT represents short-term benefits by reducing costs and increasing operational efficiency, and the strategic value of IT indicates long-term benefits by being aligned with firm strategy and enhancing the competitive advantage of the firm.

Assumption 1: The value of individual IT projects consists of two value attributes: the operational value and the strategic value.

Strategic Alignment of IT and Strategic IT Investments

Although in some companies, for instance, eBay and Google, the firm's IT leads the firm's strategy. However, in most companies, IT supports the firm's strategy, and one of the main roles of the CIO and IT managers is to align IT with the firm's strategy. In that sense, the strategic value of IT is determined by the degree to which IT is aligned with the firm's strategy. The ideal solution is that the strategic focuses and the IT focuses of the firm are an exact match and have the highest strategic value, but an exact match seems difficult to achieve because a firm's strategy is changeable and evolves, but IT investments are not highly flexible once they are implemented.

In building an IT portfolio, the strategic value or strategic alignment of IT is one of the most critical factors determining the success of the IT portfolio (Brancheau, Janz, and Wetherbe, 1996), but many IT managers have difficulty in achieving it in practice (Baets, 1992; Reich and Benbasat, 1996). Maizlish and Handler (2005), in a survey of CIOs, reported that only 52% of a firm's IT projects realized strategic value. It seems that most IT managers are aware that investments for strategic IT are important, but major projects do not have high strategic value. We argue that the reason for this discrepancy is that investments in strategic IT are riskier than investments in operational IT (Weill, 1990). In other words, the variance in the expected strategic value of IT is high. In general, returns from strategic IT investment can be achieved in the long term; thus, the investment in strategic IT projects could be worthless if a firm's strategy has changed while the project is being implemented. Therefore, in developing our model, we assumed that the average strategic value of IT projects would be higher with higher risk and with average operational value.

Assumption 2: The expected operational value of IT is characterized by lower returns with lower risk, and the expected strategic value of IT is characterized by higher returns with higher risk.

MODEL DEVELOPMENT

We applied the data envelopment analysis (DEA) method in that we selected IT projects based on efficiency rankings of proposed projects. DEA is a mathematical method that calculates the efficiency of decision-making units based on inputs and outputs of the units and then ranks the decision-making units (Cooper, 2005). In this study, the decision-making units were the individual proposed IT projects; thus, we identified the efficiency of proposed IT projects and ranked them. IT portfolios could then be selected by rank.

Operational Value vs. Strategic Value of IT

From interviews with senior IT managers in three US Fortune 500 companies, we found that these companies commonly tried to achieve a balance between operational IT projects, the values of which were mostly achieved in the short term, and strategic IT projects, the values of which were mostly achieved in the long term. Two companies of the three were using scoring models, in which they measured various values of individual IT projects for project selection. Although the two companies had different attributes in their scoring models, those attributes could commonly be classified into two categories: operational value and strategic value. Here, the operational value of IT refers to short-term benefits that are achieved by an enhancement in productivity, a reduction in costs, and an instantaneous solution to problems that a firm faces. The strategic value of IT refers to long-term benefits that give a firm a competitive advantage, for instance, through product innovation or cooperative IS with customers and suppliers. We assumed that the value of an IT project consisted of the two attributes. Then, if *n* projects were proposed, we formulated the aggregate value of the *j*th IT project, Y_j, as:

$$Y_{jt} = G_{jt} + H_{jt} \qquad\qquad (j = 1, \ldots, n), \qquad\qquad\qquad (1)$$

where G_{jt} and H_{jt} represent the operational value and the strategic value, respectively, of IT project *j* at time *t*. Equation (1) is equivalent to our *Assumption 1*.

In an empirical study, Weill (1990) found that investments in strategic IT are long-term investments and are characterized as having a higher expected value and higher risk than investments in nonstrategic IT. Strategic IT creates an opportunity for competitive advantage to the firm, which will result in higher return than operational IT. On the other hand, investment in strategic IT is riskier because the return on investment in strategic IT is achieved in the long-term period, and because today, strategic IT may not be aligned with the firm's strategy and have little strategic value 5 years later. Operational IT projects are generally well structured and well defined, and the return on projects can be relatively well estimated. Thus, the variance in the strategic value of IT is assumed to be greater than that of the operational value of IT (McFarlan, 1974).

Figure 1 illustrates our assumptions for characteristics of the operational value and the strategic value of IT. Line 1 represents the expected value of a virtual IT project that has only operational value without any strategic value, and line 2 represents the expected value of a virtual project that has only strategic value without any operational value. The narrower lines above and below the thicker lines represent maximum and minimum values, respectively, and thus indicate the range of the realized value. The figure illustrates that the average strategic value of IT is greater, with higher risk, than the average operational value of IT. The notations in Figure 1 are as follows:

- α represents the expected return from the operational value attribute of the IT project, and β represents the expected return from the strategic value attribute of the IT project. β is assumed to be greater than α, on average.
- r_o refers to the variance of the expected operational value of the IT project, which represents the level of risk of the operational value, and r_s refers to the variance of the expected strategic value of the IT project, which represents the level of risk of the strategic value aspect. We assume that r_s is greater than r_o, on average.
- t_1 represents the short-term period when the marginal value of the operational attribute of the IT project becomes nearly zero or negligible, and t_2 represents the long-term period when the marginal value of the operational attribute of the IT project is nearly zero.
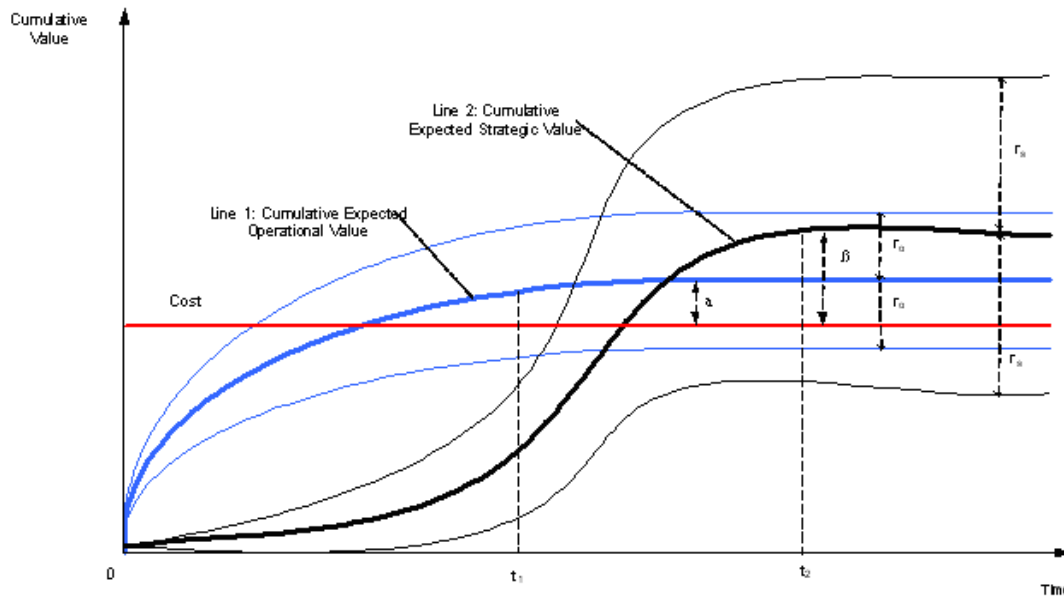
Figure 1. Assumptions for the operational value and the strategic value of IT projects

Efficient Frontier

The basic idea in our IT portfolio selection (ITPS) model is to rank projects according to their efficiency and to select projects based on this ranking. In our study, we apply the efficient frontier and efficiency defined in DEA. The efficiency of individual IT projects is derived from the distance between the position of an IT project and the efficient frontier. The efficient frontier of an IT portfolio can be defined as the set of IT projects that yields the highest expected return, given a specific expected cost; the set should have the minimum expected cost, given a specific expected return.

Different DEA models have slightly different definitions of the efficient frontier. For example, the efficient frontier in the Banker-Charnes-Cooper (BCC) model described in Figure 2 is the set of lines that connect the IT components, the efficiency of which equals one. The efficient frontier is the intersection of the set of portfolios with the minimum cost and the maximum expected return. The efficiency of an IT component, the efficiency of which is not one, is defined as the ratio between the maximum expected return, given the specific cost of the IT investment, and the actual expected return of the IT component.

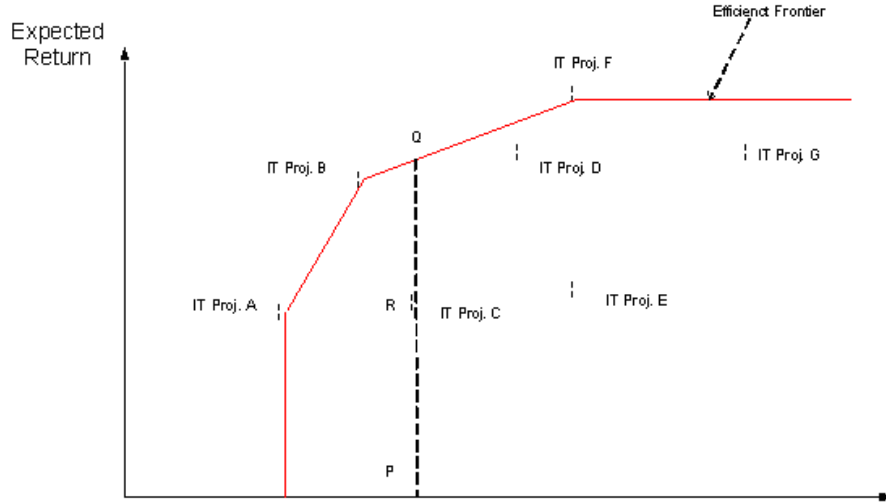For instance, in Figure 2 the efficiency of IT component C is calculated by $\overline{RP}/\overline{QP}$.

Figure 2. Efficient frontier

ITPS Models

ITPS model is a measure of the efficiency of each proposed IT project, given the data on expected IT values as outputs and the expected cost as inputs of IT projects. Suppose we have *n* proposed IT projects to evaluate; let an IT project *j* be evaluated, where *j* ranges over 1, …, *n*. Here, *n* refers to the number of proposed IT components in a portfolio selection problem. The objective function of the model is to maximize the weighted sum of the operational value and the strategic value. Using the output-oriented one-input one-output DEA model, we defined the ITPS model as shown below:

$$\underset{u,v}{Max}\,\theta = \frac{u[(1-w)g_{jt} + wh_{jt}] - u_0}{vx_{jt}}, (j = 1, …, n) \tag{2}$$

subject to

$$\frac{u[wg_{jt} + (1-w)h_{jt}]}{vx_{jt}} \leq 1$$

$$0 \leq u \leq 1$$
$$0 \leq v \leq 1$$

where θ is the efficiency of an IT project, g_{jt} and h_{jt} represent the expected operational value and the expected strategic value, respectively, of IT project *j* at time *t*, and *u* and *v* is the output weight and the input weight that maximize the efficiency in the DEA. The variable u_0 is a free variable that is defined in the DEA, particularly in BCC models. If u_0 is zero, the model above will be an application of the Charnes-Cooper-Rhodes (CCR) model, which can be regarded as a simplified BCC model. In the following section, we applied the BCC model to illustrate an example of IT portfolio selection, but applied the CCR model in our computational study in the simulation program for technical reasons.

The parameter *w* is the weight of the strategic value in IT portfolio selection and 1 − *w* is the weight of the operational value. Our study focuses on the impact of weight *w*, which represents the problem of balancing the operational value and the strategic value of the firm. *w* = 0.5 indicates firms that put importance equally on the strategic and operational values of IT portfolio, whereas *w* < 0.5 indicates firms that put more weight on the operational value, and *w* > 0.5 indicates firms that put more importance on the strategic value. The choice of the *w* value could also be influenced by whether the firm seeks long-term or short-term benefits. The longer term benefit a firm desires, the larger *w* will be.

COMPUTATIONAL STUDY OF ITPS MODELS

Method

In this section, we examine the effect of strategic IT investments in the context of IT project selection by using computational methods. As a first step, we generate project data. Second, we select projects using the ITPS model. Third, we generate the realized value of selected projects with simulated IT risks. With the realized aggregate value of the selected IT portfolio, we test our hypotheses. For this study, we developed a program using Java language. The main functions of this program were (1) to generate project data, given the costs of individual projects, which were based on *Assumption 1*; (2) to select an IT portfolio based on the ITPS model; (3) and to simulate the realized value of each IT portfolio based on *Assumption 2* and calculate the ROI (Return on Investment) and the profit from it.

Generate Project Data

We generated 100 sets of 50 proposed project data. The data sets represent the situation in which a firm has 50 proposed projects and has to select an IT portfolio, and 100 iterations of the decision are simulated. The cost of IT projects is based on the distribution of real project data we collected from two US Fortune 500 firms. For the expected operational value and the expected strategic value of the IT project, we assumed that the expected aggregate value of the proposed projects was greater than the cost of the project, because proposed projects whose expected value is less than the cost would not be considered at all by the firm. Thus, we formulated $g_j = x(0.5 + 2*random)$ and $h_j = x(0.5 + 4*random)$ at $t = t_2$ (Figure 1) for the long-term evaluation, and $g_j = x(0.5 + 2*random)$ and $h_j = x(0.25 + 1*random)$ at $t = t_1$ for the short-term evaluation, which were driven by our assumptions in Figure 1. The *random* represents the random number whose range is from 0 to 1. The two 0.5's in g_j and h_j mean that the aggregate value of any proposed IT project should be greater than the cost at the long-term evaluation. The parameters 2 and 4 that are multiplied by the random number in the formula for the long-term evaluation represent the range of the operational value and the strategic value, respectively. Because the strategic value at the long-term period is more difficult to estimate and its expected benefits are greater than the operational value, we used 4 and 2 for the strategic value and the operational value, respectively. On the contrary, in the short-term evaluation, the expected benefit from the strategic value would not be achieved, whereas the expected benefit from the operational value would be almost entirely achieved; thus, we used the parameters 0.25 and 0.5 for the operational value and the strategic value, respectively. In addition, IT managers would not expect too much for the strategic value in the short-term; thus, we used the parameters 2 and 1 in g_j and h_j, respectively.

Select an IT Portfolio

Using the ITPS models developed in the section above, we selected an IT portfolio from among 50 projects. We applied a BCC model in the IT Portfolio Example section above, but in our simulation program we applied the CCR model, in which the free variable was zero for a technical problem. However, because both the CCR and BCC models use common core algorithms that calculate efficiency by the ratio between the input and the output of decision-making units and rank them, the results would make little difference in most cases, particularly for the size of 50 decision-making units. We assumed that the firm had an IT budget of 60% of the total cost of the proposed IT projects. For instance, if the total expected cost of all proposed IT projects was $100 million, only $60 million would be available to fund IT projects. Our Java program calculated the efficiency of projects and ranked the proposed IT projects based on efficiency. The rankings enabled us to select projects from the highest ranked project up to the IT budget. That is to say, we selected the IT project using two criteria: (1) rankings from a DEA and (2) an IT budget < 0.6*(*Required budget for all proposed projects*).

Simulate Realized Value of IT Projects

The following formula represents the realized value of selected projects, which reflects the risk effects of IT projects:

$$Realized\ value\ (Y_{pt}) = g_{it} * [1 + d_1 * NI\ (random)] + h_{it} * [1 + d_2 * NI\ (random)],\qquad(3)$$

where *NI ( )* is the inverse of the standard normal cumulative distribution. The variables d_1 and d_2 indicate risk levels of the operational value and the strategic value, respectively. According to *Assumption 2*, which is based on Weill's (1990) finding that strategic IT investments are riskier than operational IT investments, d_2 should be greater than d_1 in our computational model. For example, in this study we used the value of 0.3 for d_1 and 0.5 for d_2 to test some our hypotheses.

Hypotheses

In this section, we investigate the effect of various parameters in the ITPS model on outcomes of project selection. As w in equation (2) has a higher value and approaches one, less strategic IT projects will be selected and the IT portfolio will comprise mostly operational IT projects. Depending on the value of w that IT managers choose in the IT project selection model, different sets of IT projects would be selected. Because interest in selecting IT projects centers on the operational benefits, and many IT managers have found that aligning IT investments with firm strategy is hard to achieve, we compare the outcome of two IT portfolios that are selected with different w's, for both the short-term evaluation and the long-term evaluation. We argue that most IT managers are risk-averse and are more concerned about short-term benefits than long-term benefits; thus, they mainly focus on the operational value when selecting IT projects. In particular, we compare the outcome of an IT portfolio selection with $w = 0.5$, in which both the operational value and the strategic value of individual projects are considered equally, and that of an IT portfolio selection with $w = 0$, which indicates that only the operational value of IT projects is considered. We hypothesized that the outcome of project selection with $w = 0.5$ would be more profitable than that of project selection with $w = 0$ in the long term at $t = t_2$ (Figure 2); on the contrary, the outcome of project selection with $w = 0$ would be more profitable than that of project selection with $w = 0.5$ in the short term at $t = t_1$.

> *Hypothesis 1a*: At the long-term evaluation ($t = t_2$), an IT portfolio selected from a model that considers both the operational value and the strategic value of IT projects equally ($w = 0.5$) will result in greater than an IT portfolio selected from a model that considers only the operational value of IT projects ($w = 0$), given an IT budget.

> *Hypothesis 1b*: At the short-term evaluation ($t = t_1$), an IT portfolio selected from a model that consider only the operational value of IT projects ($w = 0$) will result in greater performance than an IT portfolio selected from the model that considers both the operational value and the strategic value of IT projects equally ($w = 0.5$), given an IT budget.

One of the main assumptions in our study was that the risk of the strategic value would be greater than that of the operational value. In our simulation model, the characteristics of the value attributes are reflected in equation (2). The risk of an IT project is defined as the theoretical variance of the expected return, and is indicated by the parameters d_1 and d_2 in equation (2). A greater d_1 indicates an environment in which the operational IT investment is riskier, and a greater d_2 indicates an environment in which the strategic IT investment is riskier.

Assuming that IT managers behave risk-aversely, we can conjecture that IT managers will tend to consider the operational value as being more important as d_2 increases. In portfolio optimization theories in finance, minimizing the risk is one of the subobjective functions. Therefore, we hypothesized that, when the ITPS model with $w = 0.5$ is used, the IT portfolio selected under an environment of riskier strategic IT investments would show inferior performance compared with the IT portfolio selected under an environment of less risky strategic IT investments.

> *Hypothesis 2*: At both the long-term and short-term evaluation, when the operational value and the strategic value of IT projects are considered equally in IT portfolio selection ($w = 0.5$), the IT portfolio selected under the circumstance in which the strategic value of the IT projects is riskier will result in inferior performance of IT.

Results and Analysis

To test these hypotheses, we compared the outcome statistics of 100 sets of IT portfolio selection, including the ROIs of IT portfolios selected by the ITPS model with various w's.

Impact of the Strategic Value in IT Portfolio Selection

In the computational study, we found that the IT portfolio selected by the ITPS model with $w = 0.5$ yielded a higher ROI than the ITPS model with $w = 0$ in spite of the higher risk of the strategic IT investment in the long-term evaluation. This result supports *Hypothesis 1a* and implies that IT portfolio selection that is based only on operational benefits will result in lower performance than IT portfolio selection that considers both the operational value and the strategic value as its objective function. But, as discussed in an earlier section, the interest of many IT managers centers on the operational value of IT rather than on the strategic value. According to our interviews with CIOs of US Fortune 500 firms, in which they categorized IT projects into operational (productivity) projects and strategic projects, we also found that fewer than 20% of IT projects out of all approved projects belonged to the category of strategic IT projects. There are several possible explanations for this practice. First, assuming that the firm behaves risk-aversely, they prefer less risky IT investments. Second, the decision maker, who is, in general, a short-term positioned agent, may prefer operational projects so that she or he can achieve a

positive return from IT investments during her or his term. Thus, even if the decision maker recognizes the higher expected return from strategic investments rather than operational investments, she or he would select an IT portfolio that focuses more on operational values.

It was surprising to find that, in the short-term evaluation ($t = t_1$), the realized value of the IT portfolio selected from the ITPS model with $w = 0$ was not greater than that of the IT portfolio selected from the ITPS model with $w = 0.5$. The time $t = t_1$ represents when the marginal return has become almost zero or negligible and a significant strategic value has not yet been achieved. This result does not support *Hypothesis 1b*. As we assumed in Figure 1, the expected operational value is greater than the expected strategic value, because the strategic value is not fully achieved in the short-term period; thus, we hypothesized that the ITPS model with $w = 0$ would yield a profitable IT portfolio. It seems that the higher variance of the expected strategic value influenced the realized value of the IT portfolio. In the context of project selection, the strategic IT investment might result in a higher return than the operational investment even for the short-term period $t = t_1$.

		Long-term evaluation ($t = t_2$)		Short-term evaluation ($t = t_1$)	
		IT portfolio selection with $w = 0$	IT portfolio selection with $w = 0.5$	IT portfolio selection with $w = 0$	IT portfolio selection with $w = 0.5$
Return (= realized value – cost)	Sample mean	702.65	777.14	423.76	429.91
	Sample variance	4442.30	4137.94	855.55	712.47
	t-value	8.041478		(–)	
ROI	Sample mean	4.39	4.86	2.65	2.67
	Sample variance	0.17	0.16	0.031	0.027
	t-value	8.238343		(–)	

Table 1. Statistics for testing *Hypothesiss 1a* and *1b*

Impact of Risk of the Strategic Value in IT Portfolio Selection

We found that the risk level of the strategic value of IT projects appears not to significantly affect the outcome of IT portfolio selection. Although we obtained statistics for the realized returns and ROIs of 100 IT project data sets, the difference between the ITPS models seemed not to be significant. This was also a surprising result because in financial portfolio theory, one of the subobjectives in the portfolio optimization model is to minimize the risk of investments. The results showed that *Hypothesis 2* was not supported.

	Return (= realized value – cost)		ROI	
d_2	Mean	Variance	Mean	Variance
0.5	777.14	4137.94	4.859	0.163
0.6	777.47	5339.65	4.861	0.211
0.7	777.80	6762.53	4.864	0.267
0.8	778.14	8406.56	4.866	0.332

Table 2. Statistics for testing *Hypothesis 2*

Validation

The key issue for the validity of our computational study was the random generator. Four random generators were used in our computational study. Unless the randomly generated numbers were uniformly distributed and independent, our results may not be generalized. We used multiplicative linear congruential generators (MLCGs), $Z_i = (48,271*Z_{i-1}) \mod (2^{31} - 1)$ with seed of 3446 and of 6443 for the two random generators in the project data generation, and seed of 33446 and of 6443 for the

two random generators in the realized value simulation. We tested the distribution uniformity and independency using the Kolmogorov-Smimov (K-S) test; one-, two-, and three-dimensional chi-squared tests; a runs test; and lagged correlation tests (Law and Kelton, 1999). We found that all four random generators generated uniformly distributed numbers and that the numbers were independent from each other; thus, we can say that those random generators were good enough. The test results are summarized in the Appendix A.

Another validity issue in our computational study was the sample size. We tested our hypotheses with 100 sets of IT portfolio selection. If the size was too small, we would have gotten different results when we used different random generators. We found that even when we used different random generators, the results for our hypotheses were the same. Therefore, the sample size of 100 appeared not to have any problems. We summarize the statistics for this test in the Appendix B.

CONCLUSIONS

Our study provides a framework for IT portfolio selection for a firm. The ITPS model captured the dichotomy of the business value of IT and those characteristics. One of the contributions of this study is that we understand the problem of strategic IT investments as the problem of balancing return and risk in investments. There will be no silver bullet method for IT portfolio selection by a firm, because each firm has different IT resources, business settings, IT needs, and environments. Our model captures the essence of the IT portfolio selection problem, namely, that of balancing operational IT investments and strategic IT investments, by applying the Markowitz portfolio selection theory. According to our field studies, this is likely to be a common problem that most companies are facing.

The methodological contribution is that this study uses a computational method to hypothetically test the effect of risk in IT portfolio management. We showed the way that a computational method is used in project selection research. Since Fox and Baker (1985) used a simulation program to support their research arguments, few studies have made use of computational methods for project selection research. We believe our study demonstrates an example of the use of the computational method and is able to motivate other studies that use computational methods in the research stream of project selection and IT investment. In addition, our computational methodology can be applied other decision making problems of which core issues are balancing return and risk.

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Appendix A

Multiplicative linear congruential generators (MLCGs)

$z = (a*z_0+c) \bmod m$

, where

$a = 48271$

$m = 2^{31} -1$

$c = 0$

z_0 : seed

		Random Generator (RG) Seeds			
		3446	6443	33446	6443
K-S test	Dn	0.012279	0.00347	0.002062479	0.002852915
	D*	1.064882	0.88850	0.528239076	0.730684276
	Distribution (Result)	Uniform	Uniform	Uniform	Uniform
1-d Chi-square test	Sum of errors (SE)	4086.1141	4164.43	3983.6595	4082.4004
	$Pr(X40952 \geq SE)$	0.5362	0.22	> 0.5	> 0.5
	Distribution (Result)	Uniform	Uniform	Uniform	Uniform
2-d Chi-square test	Sum of errors (SE)	4168.881067	4027.76	3955.233707	4168.881067
	$Pr(X40952 \geq SE)$	0.206428913	0.5	> 0.5	0.206428913
	Distribution (Result)	Uniform	Uniform	Uniform	Uniform

3-d Chi-square test	Sum of errors (SE)	3968.5504	4071.442	4238.17344	4242.491
	$Pr(X40952 \geq SE)$	0.4521	> 0.5	0.058053	0.052838
	Distribution (Result)	Uniform	Uniform	Uniform	Uniform
Runs Test	Total errors (TE)	6.90	4.25	7.33	5.70
	$Pr(X62 \geq TE)$	0.3302	0.642885	0.291404	0.457621
	Distribution (Result)	Independent	Independent	Independent	Independent
Lagged Correlation	Distribution (Result)	Independent	Independent	Independent	Independent

Appendix B

Additional Tests for *Hypothesis 1a* with different Random Generators ($t = t_2$)

Random Generator (RG) Seeds				Mean ROI when $w = 0$ ($n = 100$)	Mean ROI when $w = 0.5$ ($n = 100$)	Result
RG 1	RG 2	RG 3	RG 4			
3441	34410	60233	6023	448.87%	493.35%	Support
3489	35530	63378	5748	442.54%	487.20%	Support
4859	39985	76652	9876	444.21%	492.89%	Support
1699	82346	52262	3462	439.21%	486.79%	Support
9347	26473	74373	4537	440.83%	490.28%	Support

Additional Tests for *Hypothesis 1b* with different Random Generators ($t = t_1$)

Random Generator (RG) Seeds				Mean ROI when $w = 0$ ($n = 100$)	Mean ROI when $w = 0.5$ ($n = 100$)	Result
RG 1	RG 2	RG 3	RG 4			
3441	34410	60233	6023	266.82%	271.28%	No Support
3489	35530	63378	5748	264.41%	268.60%	No Support
4859	39985	76652	9876	267.84%	270.83%	No Support
1699	82346	52262	3462	265.52%	270.08%	No Support
9347	26473	74373	4537	264.14%	268.45%	No Support