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12-14-2009

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### Recommended Citation

Chiang, I. Robert and Nunez, Manuel A., "Strategic Planning and Project Selection for IT Portfolio Management" (2009).

*International Research Workshop on IT Project Management 2009*. 10.

<http://aisel.aisnet.org/irwitpm2009/10>

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# **Strategic Planning and Project Selection for IT Portfolio Management**

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## **ABSTRACT**

Software project proposals, solicited from various sources across an organization, could significantly vary in strategic value, overlap in functionality, and assume conflicting technical infrastructure. Without a holistic approach toward project selection and planning, the resulting project portfolio will likely incur undue risk while delivering poor return on investment. We propose a two-stage optimization procedure. In the first stage, project characteristics such as strategic alignment, perceived benefits, cost, and risk are considered to maximize portfolio value. In the second stage, inter-project dependencies and team expertise are used to determine how projects are assigned to programs and in what sequence they should be carried out. Future extension on the proposed optimization procedure is also discussed.

## **Keywords**

IT portfolio management; program management office; project selection; project assignment; IT strategic alignment

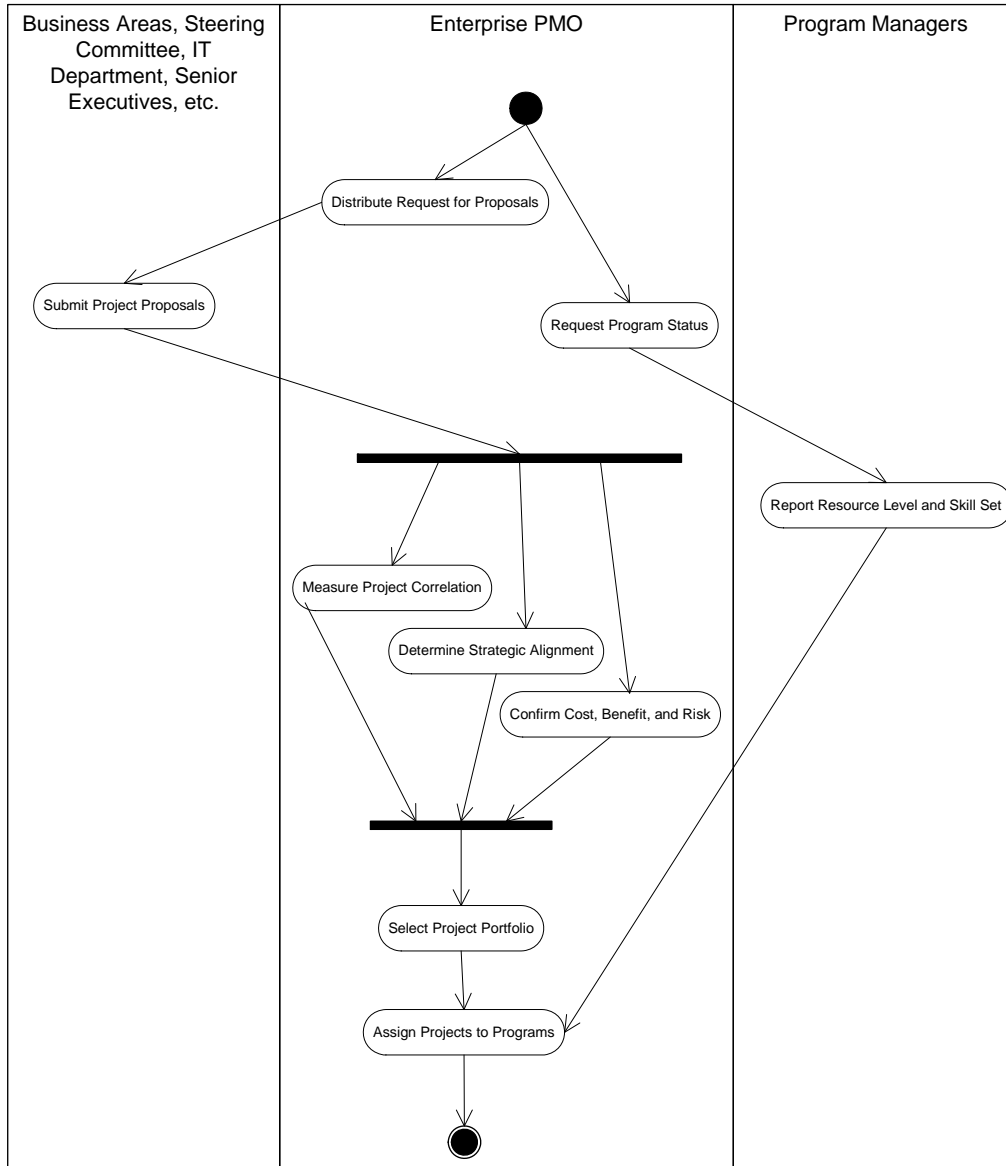
## **INTRODUCTION**

Software systems play a key role in many business initiatives to gain competitive advantage, operational efficiency, and regulatory compliance. Consequently, there has been a realization that innovations and improvements are often attainable only with the support of the underlying software systems (Foley 2009, Brynjolfsson and Schrage 2009). This realization has also led to demand for proper alignment between business and IT (Weill and Ross 2004) to ensure business needs and CEO agendas can be catered to.

Without proper IT governance, the proliferation of applications and growing complexity of the underlying technical infrastructure invariably would lead to bloated IT budget and dwindling returns on IT investment (Light 2009). To gain visibility and accountability into the IT planning and operation, an emerging trend has been to establish an enterprise program management office (EPMO) to oversee programs for new projects, active applications, and technology-related assets. In this paper, we focus on the management of new projects, with the understanding that the same decision process proposed here can be expanded to include other asset classes.

R&D project selection in general (Granot and Zuckerman 1991) and IT portfolio management in particular have received significant attention from both academics and practitioners (Stantchev, Fanke, and Discher 2009, Costa, Barros, and Travassos 2005). It is noted that, while previous studies have focused on factors such as strategic alignment (Thomas and Baker 2008), risk analysis (Costa, Barros, and Travassos 2005, Nozick, Turnquist, and Xu 2004), project scheduling (Yamashita, Armentano, and Laguna 2007), and resource allocation (Chen and Askin 2009, Ngo-The and Gunther 2009), to the best of our knowledge there has not been work that examines all of these factors jointly. A variety of research methods have been adopted for project portfolio optimization. We here follow the quantitative methods track (Keidenberger and Stummer 1999) that includes techniques such as mathematical programming, simulation (Powers, Ruwanpura, Dolhan, and Chu 2002), and greedy heuristics (Zhao et. al. 2008).

We aim to improve the decision process shown in the following swimlane diagram:



**Figure 1. Portfolio Management Process**

The process starts with selecting projects into the portfolio. First, project proposals are solicited across the organization (including the IT department) and from various levels of management hierarchy. Then, project prioritization—based on organizational, financial, and technical criteria—takes place to maximize portfolio values without exceeding the budget limit or the level of risk tolerance. Selected projects are then assigned to one of the several programs for development.

We next present the optimization model and will describe the steps within the decision process in more detail.

## MODEL FORMULATION

We consider a two-stage optimization model. In the first stage we optimize the overall value of the projects selected to be in the portfolio. In the second stage we optimize the assignment of selected projects to development teams within the programs so as to minimize the completion time of the overall portfolio.

We use the following notation in the first-stage model:

- $i$ : Project index
- $j$ : Strategic objective index
- $M$ : Index set of projects
- $N$ : Index set of objectives
- $u_i$ : Probability of zero return of project  $i$  ( $0 \leq u_i \leq 1$ )
- $r_i$ : Return of project  $i$  ( $r_i \geq 0$ )
- $c_i$ : Implementation cost of project  $i$  ( $c_i \geq 0$ )
- $s_{ij}$ : Strategic contribution of project  $i$  to objective  $j$  ( $0 \leq s_{ij} \leq 1$ )
- $w_j$ : Weight of objective  $j$  ( $w_j \geq 0$ )
- $d_{ii'}$ : Cross-project dependency between projects  $i$  and  $i'$  ( $-1 \leq d_{ii'} \leq 1$ )
- $B$ : Available budget ( $B \geq 0$ )
- $U$ : Risk tolerance ( $0 \leq U \leq 1$ )
- $X_i$ : Binary decision variable (= 1 if project  $i$  is selected; = 0 otherwise)
- $\beta$ : Sensitivity to strategic alignment ( $0 \leq \beta \leq 1$ )

When project proposals are submitted to the EPMO for consideration, in addition to the opportunity/need statement, we assume each proposal also includes high-level estimates on expected benefits and required (financial and personnel) resources. A preliminary risk assessment may also be provided.

The EPMO evaluates each proposal to assess its alignment with the organization's overall missions, goals, and strategic objectives. This is often accomplished by soliciting inputs from senior executives. To measure the extent that the project portfolio is aligned with the organization's strategy, we define a strategic alignment ( $SA$ ) measure as follows:

$$SA = \sum_{i \in M} \sum_{j \in N} w_j s_{ij} X_i$$

Since certain goals may be more critical than the others, we use a weighting coefficient  $w_j$  to capture the relative importance of strategic goal  $j$ . Ideally, more consideration should be given to projects that are better aligned with a critical goal or can support more than one goal.

Besides strategic alignment, another important factor for portfolio selection is the expected return on investment. Notice the expected benefit should be risk-adjusted because higher risk implies lower likelihood that it can be successfully completed for benefit realization. We here use the project risk measure as a discount factor when estimating the project benefit.

Another important task for the EPMO is to identify the "correlation" between projects that also affects the expected return. Projects of complementary nature should be pursued jointly. For example, a project that consists of upgrading the enterprise data warehouse should be implemented together with a project that consists of enhancing the reporting capabilities using features from the upgraded warehouse. On the other hand, if two or more proposals promise to deliver similar functionalities, then only one should be chosen to avoid redundancies. For example, one functional area may propose a project that consists of implementing a SAP-based solution whereas a different functional area may suggest an Oracle-based solution, yet both projects aim to improve the same inventory tracking and reporting capability. Working with business architects, technical architects, and financial analysts, the EPMO revises the benefit, cost, and risk assessments for each proposal.

We define a measure for the expected benefit ( $EB$ ). The first term models the risk-adjusted benefit value of selected projects whereas the second term, depending on whether each project pair is complementary in nature or could cannibalize each other, augments or reduces the benefit value.

$$EB = \sum_{i \in M} (1-u_i)r_i X_i + \frac{1}{R} \sum_{i \in M} \sum_{i' \in M} (1-u_i)r_i X_i (1-u_{i'})r_{i'} X_{i'} d_{ii'}$$

where  $R := \sum_{i \in M} ((1-u_i)r_i)$  is a scaling coefficient used to normalize the quadratic form of the correlation term.

We can now formulate the portfolio selection (PS) problem as follows. To ensure project benefits, adjusted for strategic alignment and perceived risk, can be maximized for a given budget and risk tolerance, we solve:

$$(PS) \max_{X_i} \beta SA + (1-\beta) EB$$

s.t.

$$\sum_{i \in M} c_i X_i \leq B \quad (\text{Budget constraint})$$

$$\sum_{i \in M} u_i c_i X_i - U \sum_{i \in M} c_i X_i \leq 0 \quad (\text{Risk tolerance})$$

$$X_i \in \{0,1\}$$

Notice that we use the parameter  $\beta$  to adjust the relative importance of the strategic alignment contribution to the objective function with respect to the expected benefit contribution. Also, the portfolio's risk score is weighted by the project cost. Doing so allows a low-cost project to proceed if it carries both high risk and high reward. On the other hand, a very costly project should be reviewed with caution even if its risk is moderate.

Project assignment and scheduling follows the selection stage in the two-stage model. In the second stage we use the following notation:

$k$ : Program index

$K$ : Index set of programs

$f_i$ : Resources required by project  $i$  ( $f_i \geq 0$ )

$g_k$ : Resources available to program  $k$  ( $g_k \geq 0$ )

$h_{ik}$ : Time to complete project  $i$  if assigned to program  $k$  ( $h_{ik} \geq 0$ )

$T_k$ : Total time required to complete all projects assigned to program  $k$  ( $T_k \geq 0$ )

$Y_{ik}$ : Binary decision variable (= 1 if project  $i$  is assigned to program  $k$ ; = 0 otherwise)

With the EPMO's enterprise-wide visibility to resource bottlenecks and skill profiles, it is possible to determine how projects should be best assigned to different programs for development.

Another opportunity for improvement is production scheduling within each program by considering the precedence relationships among projects. For example, a business intelligence reporting capability is easier to develop if the underlying data warehouse has already been in place. While the precedence relation among software systems is often considered not "hard," going against the natural sequence could incur additional development, testing, and integration costs. For brevity, we consider only project assignment (PA) in the following optimization model:

$$\begin{aligned}
(PA) \quad & \min_{Y_{ik}} \max_{k \in K} T_k \\
\text{s.t.} \quad & \\
& \sum_{k \in K} Y_{ik} = X_i \quad (\text{Assignment constraint}) \\
& \sum_{i \in M} f_i h_{ik} Y_{ik} \leq g_k T_k \quad (\text{Time/resource constraint}) \\
& Y_{ik} \in \{0,1\}
\end{aligned}$$

Notice that in this formulation the variables  $X_i$  are not decision variables, they are instead input parameters that originate from an optimal solution to the first-stage problem. For a given feasible solution  $Y_{ik}$ , the expression

$$\max_{k \in K} T_k$$

represents the time to complete all the projects. Hence, we find an assignment of projects to programs that minimizes the overall completion time of all projects.

As for the complexity of solving problems  $PS$  and  $PA$ , notice that problem  $PS$  is a quadratic assignment problem and since quadratic assignment problems are well-known to be  $NP$ -Hard, it is likely that there is no efficient (polynomial) algorithm to solve it. Similarly, for a fixed assignment of values to the variables  $T_k$ , problem  $PA$  becomes a binary knapsack problem, another well-known  $NP$ -Hard problem, and so, it is also likely that it does not have an efficient algorithm to solve it.

### SCENARIO ANALYSIS

We consider several scenarios to illustrate the interaction of the different optimization factors in play within our model formulation. We start analyzing the effect of return and risk on the optimal solution in a situation where the strategic alignment is the same for all projects under review. Consider a portfolio selection problem with five candidate projects and two equally weighted strategic goals. The following table summarizes the parameters of the problem instance.

Project	Return ( $r_i$ )	Risk ( $u_i$ )	Cost ( $c_i$ )	Return/Cost
P1	30	0.2	20	1.5
P2	50	0.2	50	1.0
P3	60	0.2	40	1.5
P4	55	0.2	50	1.1
P5	50	0.2	45	1.1

**Table 1. Scenario 1 Parameters.**

We also assume that the strategic contribution of each project to each of the two objectives is the same ( $s_{ij} = 1$ ), and the dependencies between projects are zero ( $d_{ii'} = 0$  for  $i \neq i'$ ). The risk tolerance is  $U = 0.5$  and  $\beta = 0.5$ . Table 2 shows the results of solving the problem as the budget varies from 50 to 250.

Budget	P1	P2	P3	P4	P5	Expected Return
50	no	no	yes	no	no	48
100	no	no	yes	yes	no	92
150	no	no	yes	yes	yes	132
200	no	yes	yes	yes	yes	172
250	yes	yes	yes	yes	yes	196

**Table 2. Optimal Solutions as the Budget Varies in Scenario 1.**

Notice that as the budget increases more projects are selected and the selection is driven by the ratio of the return to the cost as expected. For instance, when the budget is 100, projects P3 and P4 are selected. As the budget is increased to 150, we have a choice between projects P2 and P5, both with returns of 50 each. However, project P5 is selected because it has a higher return to cost ratio than project P2.

Now, let us assume that the budget is fixed at 250, so that all the projects will be selected. In the second stage we consider assigning the projects to two different programs. Table 3 shows the corresponding parameters.

Project	Resources needed ( $f_i$ )	Time per Program ( $h_{ik}$ )	
		Program 1	Program 2
P1	2	30	60
P2	3	30	60
P3	4	60	40
P4	5	60	40
P5	6	90	60
Available resources ( $g_k$ )		10	10

**Table 3. Parameters for the Second-Stage Problem**

The optimal solution is shown in Table 4. The projects are assigned so as to strike a balance between the total time that each program will take in completing their corresponding assigned projects. In Program 1 the total time required to complete projects P1, P2, and P4 is 45 whereas in Program 2 the total time to complete projects P3 and P5 is 52. Notice that projects P1, P2, and P5 were assigned to the most efficient programs in terms of the  $h_{ik}$  times. The last two projects P3 and P4 with the closest  $h_{ik}$  values across programs (60 in Program 1 and 40 in Program 2) were assigned to different programs.

Project	Assignment	
	Program 1	Program 2
P1	yes	no
P2	yes	no
P3	no	yes
P4	yes	no
P5	no	yes

**Table 4. Optimal Assignment in the Second Stage.**

We next consider a different scenario in which we study the effect of strategic alignment. In the second scenario we assume that the returns, risk, and cost are the same for all the projects, but the contributions to strategic goals change as indicated in Table 5. Concretely, we assume that all the projects have the same return ( $r_i$ ) of 50, same risk ( $u_i$ ) of 0.2, and same cost ( $c_i$ ) of 20. All the remaining parameters remain the same as in the first scenario.

Project	Strategic Goal Contribution ( $s_{ij}$ )	
	G1	G2
P1	0.5	1
P2	1	0.8
P3	1	0.5
P4	0.6	1
P5	1	1

**Table 5. Scenario 2 Parameters.**

Table 6 shows the optimal solutions as the budget ranges from 20 to 100. Projects are greedily selected according to their net contribution to strategic alignment.

Budget	P1	P2	P3	P4	P5	Strategic contribution
20	no	no	no	No	yes	1
40	no	yes	no	No	yes	1.9
60	no	yes	no	Yes	yes	2.7
80	no	yes	yes	Yes	yes	3.45
100	yes	yes	yes	Yes	yes	4.2

**Table 6. Optimal Solutions as the Budget Varies in Scenario 2**

Finally, we consider a scenario where the cross-project dependency plays a significant role in the selection of projects. In this scenario we assume the same parameters  $r_i$ ,  $u_i$ , and  $c_i$  as in the second scenario, except that we set the budget at  $B = 45$  and  $c_5 = 80$ , so that only two projects from P1, P2, P3, and P4 can be selected. Also, we set the dependency between projects P1 and P2 as  $d_{12} = -1$ , and between projects P3 and P4 as  $d_{34} = -1$ . That is, the pair (P1,



P2) and the pair (P3, P4) represent pairs of substitutable projects. Finally, we set the matrix of contributions to strategic goals as shown in Table 7.

Project	Strategic Goal Contribution ( $s_{ij}$ )	
	G1	G2
P1	1	1
P2	1	1
P3	0.5	0.5
P4	0.5	0.5
P5	1	1

**Table 7. Scenario 3 Parameters.**

Using  $\beta = 0.9$ , the optimal solution is to select projects P2 and P4. If we only take into consideration the contribution to strategic alignment as given in Table 7, the optimal solution seems counterintuitive because projects P1 and P2 contribute the most. However, because projects P1 and P2 have a negative  $d_{ij}$  dependency (they are substitutable of each other and become redundant if chosen into the portfolio together), their joint contribution to expected benefit  $EB$  is lower than the contribution to  $EB$  of projects P2 and P4 together.

## DISCUSSION AND CONCLUSION

In this paper we have proposed an optimization procedure for project portfolio and program management with several salient features. First, we propose the use of a strategic alignment measure to ensure that projects with high strategic significance are given preferred consideration. Second, the use of cross-project dependencies helps to screen out competing proposals, minimizing the likelihood of selecting multiple projects with overlapping functionality. Third, we also optimize the expected return of the portfolio and incorporate a measure of portfolio risk. Finally, based on an optimal portfolio selection, we indicate how to optimally assign the projects to different programs so as to minimize the overall completion time of all the selected projects. The models suggested here can be used by decision makers to provide an end-to-end support for portfolio optimization.

Leading project management tools, such as Microsoft Office Enterprise Project Management solution, are capable of capturing many of the decision variables discussed in the paper, such as expected return, risk, and strategic goals, to facilitate portfolio decisions. In addition, several approaches can be implemented to determine parameters such as contribution of a project to strategic goals. For example, the company can use a Delphi approach in which a group of key managers and consultants can independently rate (on a scale) each project's contribution to individual strategic goals. Many companies also rely on enterprise architects to perform such function to avoid missed or duplicated coverage on strategic goals. Because, first, there is no significant change to the portfolio management process when incorporating strategic alignment and project correlation, and second, project assignment can be significantly accelerated, we consider our approach to be practical, feasible, and beneficial.

For immediate extensions of our research, we are in the process of developing a more robust model for the second stage that will determine the scheduling of the projects within each program. It is often the case that program managers have certain flexibility in the order they can execute the projects and in some cases, it makes sense to deviate from the natural or expected sequence to better use resources. The tradeoff is that it could become necessary to incur a coordination cost for projects executed out of sequence. Another extension is to expand the current budget constraint in the first stage by adding the scheduling costs from the second stage as a feedback process. That way the two stages will have to be optimized simultaneously until reaching an equilibrium point. We plan to incorporate these issues in future refinements of our second stage problem. In addition, sensitivity analysis can be performed to study how robust the model is when subject to small changes in parameters. Simulation can also be used to forecast the performance of the portfolio solution derived from our model before implementing it.

We also plan to expand our model beyond new project initiatives to include decisions for existing applications. The goal is to provide insights on determining whether active applications should be terminated, replaced, refreshed (either through functionality enhancement or infrastructure upgrade), or consolidated.

To empirically test our model, we plan to start with reanalyzing past project portfolios (while incorporating new factors proposed in this paper) and assess whether there is a post ante improvement over the original decisions. Finally, we also aim to add a user interface so that the proposed approach potentially can be integrated as part of the decision aid for ongoing IT governance and portfolio management.

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