Abstract—IT departments are caught between a rock and a hard place these days. Budgets are shrinking while the dependence on IT products and services is increasing. The pressure to demonstrate that each new project will either save money, increase sales, or result in enterprise-wide efficiencies is greater than ever. And yet, the majority of Global 1000 companies are still choosing which projects get funding either by the first-come/first served method, the squeaky-wheel gets the grease method, or the most powerful sponsor method. Deciding which IT projects get funding should be based on more than just subjective judgment; rather, the project should be analyzed objectively, looking at a number of factors – cost of ownership, cycle time, quality, risk, and benefit(s) being just a few. By analyzing projects objectively, they can be more effectively prioritized. CIOs and IT managers can then make wiser and more insightful decisions about which projects should get funding and which should be either postponed or shelved.

1. INTRODUCTION

Purpose
The purpose of this paper is to establish some basic taxonomy for the notion of portfolio management and then to describe a process for performing the portfolio planning part of portfolio management.

Scope
The subject matter in this paper, while primarily geared to large enterprise Information Technology (IT) functions is nonetheless applicable to any enterprise seeking to improve the way it attempts to make decisions about investing in software development projects.

Background
Back during high-growth days of the "go-go ’90s," funding for Information Technology (IT) projects wasn't a big deal at many companies. If a project showed interesting potential and/or caught the eye of the right decision maker, it would likely get the thumbs-up.

Times have certainly changed, with competition for resources to complete IT projects more intense than ever. To help them prioritize multiple projects, many CIOs and IT managers are applying the principles of investment portfolio management to their portfolios of IT projects. This enables them to evaluate projects based on their contributions to the high-level strategic and financial objectives of the enterprise.

In other words, they're attempting to manage their project portfolios just like portfolios of investments – continually tracking outlays, returns, potential value and the risk of each project in order to maximize return on investment and accomplish corporate objectives. Just like an investment portfolio, the goal is to find the proper balance in their project portfolios in order to make the best investments that will maximize returns and minimize risk.

For example, a company might fund a few high-risk projects that have higher potential returns, but would want to balance...
this with other low-risk projects that offer more modest returns. Traditionally, this kind of risk-based decision making has only been applied at the individual project level – the portfolio management concept expands this to collections of projects.

The process of managing Information Technology (IT) projects using a financial investment portfolio metaphor has attracted much interest from CIOs in Fortune 1000 companies. This so-called IT portfolio management process is expected to improve returns on IT investments by ensuring that resources are funneled to those projects that will contribute the most to the company’s overall success.

2. A TAXONOMY FRAMEWORK FOR PORTFOLIO MANAGEMENT

This paper first proposes a definition for Portfolio Management that closely parallels the essence of Software Project Management as described in the Software Engineering Institute’s (SEI) Capability Maturity Model Integration (CMMI). This essence consists of key processes for Software Project Planning and Software Project Monitoring and Control. Consequently, the paper proposes that portfolio management be decomposed into analogous key elements: one called portfolio planning and one called portfolio monitoring and control. The idea is to zoom out from an individual project view (characteristic of Level 2 organizations) to one that encompasses a collection of projects associated with a particular business enterprise (characteristic of Level 3 and higher organizations).

Portfolio Planning

This paper proposes that portfolio planning is a key element of portfolio management and is analogous to the CMMI Key Process called Software Project Planning. This paper further proposes that, conceptually, portfolio planning as it relates to IT projects means making IT project investment (go – no go) decisions as some function of potential estimated Return on Investment (ROI). Historically this has sometimes been referred to as doing a cost-benefit analysis or a trade study.

Portfolio Monitoring and Control

Completing the analogy in the previous paragraph, this paper proposes that portfolio monitoring and control is a key element of portfolio management and is analogous to the CMMI Key Process called Software Project Monitoring and Control. This paper further proposes that, conceptually, portfolio monitoring and control as it relates to IT projects means using the artifacts produced by the portfolio planning process as the basis for effectively and efficiently scheduling the tasks of and allocating resources to each project in the portfolio as some function of inter-task dependencies, resource availability, and priority. There are numerous tools on the market today that have specialized in performing this process at the project level and are now offering enhancements that make this possible at the portfolio level as well.

3. PORTFOLIO PLANNING PROCESS

This paper suggests that what’s been missing from most of the discussion about the portfolio planning part of portfolio management is some clear notion of quantification; without which, objective fact-based decisions are virtually impossible to make.

This paper proposes an approach (summarized in Figure 1) that prioritizes (rank-orders) the projects in a given portfolio by a calculated value called Risk-Adjusted Relative Return on Investment (RARROI). Calculation of RARROI requires knowledge of two key estimated quantities, the project’s worth to the enterprise (relative return) and the project’s cost of ownership (risk-adjusted investment). Knowing these two estimated quantities allows the IT manager to make business decisions the same way a fund manager makes buy, sell, and hold decisions.

![Figure 1: Portfolio Planning Process Data Flow Diagram](image)

Quantifying the Risk-Adjusted Investment

The risk-adjusted investment part of RARROI can be estimated as a function of size and efficiency using a structured process that is based on accepted statistical methods and real performance data. Structured estimating methods and tools, such as r2Estimating’s r2Estimator, employ well-established solutions for this part of the problem.

Structured estimating begins by hierarchically decomposing the proposed software product into manageable pieces and then describing each piece in terms of its expected effective size. (density-adjusted volume of new and pre-existing software in SLOC, Function Points, Use Cases, etc.), its expected specific efficiency (based on relevant historical data
and/or a set of detailed environment parameters), and the associated uncertainties about each.

**Expected effective size** with uncertainty and **expected specific efficiency** with uncertainty are mathematically combined to yield calculated estimates for duration, effort, cost, staffing, and delivered defects, as well as the confidence probability distributions associated with each. It is possible, therefore, to determine a project solution where the cost of ownership (risk-adjusted investment) value has, say, an 80% confidence probability; i.e., there is an 80% probability that the actual outcome cost will not exceed this determined value. Note that 80% is merely an example; each individual enterprise must determine its own risk tolerance. Typical reasonable confidence probability values range from about 70% to 90%.

Quantifying the Return and its Associated Confidence

The return, of course, will vary tremendously from project to project as a function of the business environment. Return is very difficult to quantify in terms of some absolute units like dollars since it tends to be influenced by multiple factors such as value to the marketplace, influence on customer satisfaction, influence on enterprise productivity / quality, etc. It is much more tractable to treat return as a normalized relative value. This relative return value can be estimated straight away or it can perhaps be a weighted average of several return parameters.

Regardless of whether return is estimated in aggregate or parametrically, since relationships and influences vary from organization to organization, trying to develop specific algebraic estimation relationships (regressions) may not be the best approach. Instead, this paper proposes establishing normalized relative return values using the Analytic Hierarchy Process (AHP) [4].

**AHP Step 1**—The first step in the AHP elicits a hierarchical representation of the decision criteria. The root node of the hierarchy represents the overall objective. The leaf nodes represent the set of decision alternatives. Intermediate levels in the hierarchy represent a decomposition of the relevant attributes of the decision process; i.e., selection criteria.

**AHP Step 2**—The second step in the AHP elicits relational data for comparing the alternatives. This is done via a series of pairwise comparisons between each of the criteria at a given level in the hierarchy with respect to a criterion at the parent level (one level up). The value of a comparison \( W \) between the \( i^{th} \) criterion (\( A \)) in level \( q \) and the \( j^{th} \) criterion (\( B \)) in level \( q \) with respect to a level \( q-1 \) (parent) criterion \( U \) is assigned as follows:

\[
w_{ij} = \begin{cases} 1 & \text{for } A \text{ having the same importance as } B \text{ with respect to } U \ , \\ 3 & \text{for } A \text{ having slightly more importance than } B \text{ with respect to } U \ , \\ 5 & \text{for } A \text{ having more importance than } B \text{ with respect to } U \ , \\ 7 & \text{for } A \text{ having a lot more importance as } B \text{ with respect to } U \ , \\ 9 & \text{for } A \text{ totally dominating } B \text{ with respect to } U \ . \\ \end{cases}
\]

\[
w_{ij} = \begin{cases} \frac{1}{3} & \text{for } A \text{ having slightly less importance than } B \text{ with respect to } U \ , \\ \frac{1}{5} & \text{for } A \text{ having less importance than } B \text{ with respect to } U \ , \\ \frac{1}{7} & \text{for } A \text{ having a lot less importance than } B \text{ with respect to } U \ , \\ \frac{1}{9} & \text{for } A \text{ totally dominated by } B \text{ with respect to } U \ . \\ \end{cases}
\]

\[
w_{ij} = \frac{1}{2}, \frac{1}{4}, \frac{1}{6}, \frac{1}{8} \text{ can be used as intermediate values.}
\]

The results of the pairwise comparisons done for level \( q \) with respect a criterion at level \( q-1 \) where level \( q \) contains \( n \) criteria can be organized in a positive pairwise comparison matrix \( A \) as
\[
A = \begin{pmatrix}
  w_1 & w_1 & \cdots & w_1 \\
  w_1 & w_2 & & w_n \\
  w_2 & w_2 & \cdots & w_2 \\
  \vdots & \vdots & \ddots & \vdots \\
  w_n & w_n & \cdots & w_n \\
  w_1 & w_2 & & w_n
\end{pmatrix}
\]

(1)

where

\[
\frac{w_a}{w_b} = \text{Relative importance of the } a^{th} \text{ criterion over the } b^{th} \text{ criterion where } a, b \in 1, 2, \ldots, n.
\]

Note two important characteristics about this type of matrix:

- \( a_{ii} = 1 \) (every value on the principal diagonal of \( A \) is 1)
- \( a_{ij} = \frac{1}{a_{ji}} \) (the values on one side of the principal diagonal are the mirror reciprocals of the values on the other side of the principal diagonal).

**AHP Step 3**—The third step in the AHP determines the relative weights for each positive pairwise comparison matrix developed in Step 2. Saaty [3] introduced a method for determining the relative criteria weight vector \( W \) of a comparison matrix \( A \) using the right eigenvector of \( A \).

\[
(A - \lambda_{\text{max}} I)W = 0
\]

or

\[
\sum_{j=1}^{n} a_{ij} w_j = \lambda_{\text{max}} w_i
\]

where

\[
\sum_{i=1}^{n} w_i = 1
\]

The matrix algebra necessary to solve for \( W \) can be quite cumbersome. A convenient numerical method for approximating \( W \) is as follows:

\[
n := 1
\]

\[
A_n := A
\]

\[
W_n := \text{a column vector, the elements of which are the normalized row sums of } A_n
\]

repeat

\[
n := n+1
\]

\[
A_n := A_{n-1} A_{n-1}
\]

\[
W_n := \text{a column vector, the elements of which are the normalized row sums of } A_n
\]

until \( W_{n-1} - W_n \) is sufficiently small for all elements

AHP applied to determining relative return first determines the return parameter importance (weight) of each return parameter and then determines the relative project importance for each return parameter. The aggregate relative return for a given project is the sum of the weighted return parameters for that project.

Note that the estimation process associated with the risk-adjusted investment must be done before relative project importance for each value parameter is determined (this control dependency indicated by the dashed arrow in Figure 1) since relative importance can change as a function of the particular duration, effort, cost, staffing, and delivered defects associated with a given solution. For example, a certain value parameter could assume a greater importance (weight) for a given project if the project can be delivered sooner.

**Calculating Risk-Adjusted Relative Return on Investment (RARROI)**

Risk-Adjusted Relative Return on Investment (RARROI) is simply the ratio of the relative return to the risk-adjusted investment as shown in Equation (5).

\[
RARROI_p = \frac{\sum_{i=1}^{n} R_i W_i}{I_C}
\]

where

\[
RARROI_p = \text{Risk-Adjusted Relative Return on Investment for project } P.
\]
$R_i$ = Normalized relative project importance for the $i^{th}$ return parameter.

$W_i$ = Normalized relative parameter importance (weight) for the $i^{th}$ return parameter.

$I_C$ = Normalized relative investment (cost of ownership) with confidence percentage $C$ where $C$ represents the enterprise standard risk tolerance (desired probability of success).

**RARROI-Based Investment Decision Making**

Once **Risk-Adjusted Relative Return on Investment (RARROI)** has been calculated for each project, all that remains is to rank order the projects by descending **RARROI**. Adding a column for cumulative estimated investment in dollars provides a quick means of determining where the budget cut line should be drawn.

**An Example**

The following is a series of figures that show the sequence of the portfolio planning process steps for a portfolio of ten projects where a project’s return is determined by its importance to customer satisfaction and productivity improvement and where the enterprise’s risk tolerance has been established at 80%. The enterprise’s budget for this portfolio is $1,000,000.

**Figure 2: AHP Decision Hierarchy for the Project Portfolio’s Return Evaluation**

**Pairwise Comparison Matrix**

<table>
<thead>
<tr>
<th>Return Parameters</th>
<th>Customer Satisfaction</th>
<th>Productivity Improvement</th>
<th>Normalized Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i$</td>
<td>Customer Satisfaction</td>
<td>Productivity Improvement</td>
<td>Normalized Weight</td>
</tr>
<tr>
<td>$i$</td>
<td>1.00</td>
<td>3.00</td>
<td>0.75</td>
</tr>
<tr>
<td>$i$</td>
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<td>1.00</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Figure 3: Pairwise Comparison Matrix and Normalized Relative Weights for the Return Parameters**
### Pairwise Comparison Matrix

#### Customer Satisfaction

<table>
<thead>
<tr>
<th></th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
<th>Project 4</th>
<th>Project 5</th>
<th>Project 6</th>
<th>Project 7</th>
<th>Project 8</th>
<th>Project 9</th>
<th>Project 10</th>
<th>Normalized Weight</th>
</tr>
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</tr>
</tbody>
</table>

Figure 4: Pairwise Comparison Matrix and Normalized Relative Weights for Projects vis-à-vis Customer Satisfaction

### Pairwise Comparison Matrix

#### Productivity Improvement

<table>
<thead>
<tr>
<th></th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
<th>Project 4</th>
<th>Project 5</th>
<th>Project 6</th>
<th>Project 7</th>
<th>Project 8</th>
<th>Project 9</th>
<th>Project 10</th>
<th>Normalized Weight</th>
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Figure 5: Pairwise Comparison Matrix and Normalized Relative Weights for Projects vis-à-vis Productivity Improvement
<table>
<thead>
<tr>
<th>Project Name</th>
<th>80% Confidence Estimated Cost of Ownership</th>
<th>Relative Weight</th>
<th>Relative Parameter Value</th>
<th>Customer Satisfaction</th>
<th>Productivity Improvement</th>
<th>RARROI</th>
<th>Cumulative Investment</th>
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</table>

Figure 6: Project RARROI Calculations

<table>
<thead>
<tr>
<th>Project Name</th>
<th>80% Confidence Estimated Cost of Ownership</th>
<th>Relative Weight</th>
<th>Relative Parameter Value</th>
<th>Customer Satisfaction</th>
<th>Productivity Improvement</th>
<th>RARROI</th>
<th>Cumulative Investment</th>
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<tr>
<td>Project 7</td>
<td>$68,000.00</td>
<td>0.03</td>
<td>0.21</td>
<td>0.75</td>
<td>0.21</td>
<td>0.25</td>
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<td>0.10</td>
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<td>$108,500.00</td>
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<td>0.75</td>
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<td>Project 4</td>
<td>$173,500.00</td>
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<tr>
<td>Project 3</td>
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<tr>
<td>Project 10</td>
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<tr>
<td>Project 9</td>
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<td>Project 2</td>
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Figure 7: Projects Ranked by Descending RARROI with Budget Cut Line at $1,000,000

4. SUMMARY AND CONCLUSION

Software Information Technology (IT) project portfolio management can be viewed as consisting of two key elements: portfolio planning and portfolio monitoring and control. Time-tested software project estimation methods and tools are therefore an essential part of effective portfolio planning as they represent the best practices for estimating a project’s estimated relative return and its estimated risk-adjusted investment. These estimated values yield a project’s Risk-Adjusted Relative Return on Investment (RARROI) which, in turn, can be used as the basis for ranking and ultimately selecting the projects to be funded.
A key byproduct of the **investment (cost of ownership)** estimation process is a baseline plan, which can be used as an input to the **portfolio monitoring and control** process. Additionally, **RARROI** can be used in the **portfolio monitoring and control** process as part of the basis for setting task priorities in a pre-emptive priority-based scheduling and resource allocation scheme.

**Portfolio management** is a promising concept that needs measurement to be practical. You *can’t control* [manage] what you *can’t* [don’t] measure [1]. This paper provides a reasonably simple calculation based on existing methods and tools that can serve as a foundation for applying measurement to **portfolio planning** and therefore help bring **portfolio management** into the realm of **objective (i.e., fact-based)** decision making.

**REFERENCES**


**BIOGRAPHY**

**Mike Ross** has over 30 years of experience in software engineering as a developer, manager, process champion, consultant, instructor, and award-winning international speaker. Mr. Ross is currently the President and CEO of r2Estimating, LLC. Mr. Ross’s previous experience includes three years as Chief Engineer of Galorath Inc. (makers of the SEER suite of estimation tools), seven years with Quantitative Software Management, Inc. (makers of the SLIM suite of software estimating tools) where he was Vice President of Education Services, and 17 years with Honeywell Air Transport Systems (formerly Sperry Flight Systems) and 2 years with Tracor Aerospace where he developed or managed the development of embedded software for avionics systems installed various commercial airplanes and for expendable countermeasures systems installed in various military aircraft. He also co-founded Honeywell Air Transport Systems’ SEPG, served as its focal for software project management process improvement, and served as a Honeywell corporate SEI CMM as-