Assessing the Value of Improved Predictability Due to Process Improvements

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ABSTRACT

Many software organizations have reported the benefits of implementing process improvement activities. However, unlike many other benefits associated with process improvement such as reduced rework and productivity gains, it is difficult to associate objective financial benefits with improved predictability. We propose a technique based on a variation of the Capital Asset Pricing Model and Net Present Value to monetarily quantify the improved predictability gained by process improvement.

Keywords

Process Improvement, Economic Valuation, Project Management, Value of Information

1 INTRODUCTION

Many organizations are interested in improving their software development process. This is evidenced by the increase in organizations that have participated in SEI assessments, growing from 130 in 1991 to 1,380 in 2000, though as of February 2000 there were still only 71 "high maturity" organizations [Paulk, et.al. 2000]. Many benefits have been reported by organizations that have increased their maturity ratings. The most common are:

- reduced rework
- enhanced post delivery quality
- productivity gains
- reduction in time to market
- improved predictability

While there are many studies reporting these various benefits, in this work we are particularly interested in the benefits of *improved predictability*.

There have been many reports on the impact of higher Maturity ratings on predictability. For instance [Herbsleb, et.al. 1994; Brodman and Johnson, 1995]:

- The *Space Shuttle*, a Level 5 organization, is widely acknowledged to have the ability to predict costs within 10%.
- *Raytheon* reported that predictability of budget and schedule was "reduced" from an average 40% overrun to +/- 3% after advancing to an SEI Level 4 [Haley, et.al. 1995].
- *Motorola* reported that estimation accuracy on project schedule and effort improved to better than 90% in the process of qualifying for an SEI Level 5 rating [Diaz & Sligo, 1997].
- *Hughes*: published predictability improvement data indicating that the Cost-Performance Index (CPI) went from .94 to 0.97 in response to SEI Maturity improvements [Humphrey, et.al. 1991].

However, unlike many other benefits associated with process improvement such as reduced rework and productivity gains, it is difficult to associate objective financial benefits with improved predictability.

2 PREDICTABILITY

Predictability is often confused with increased productivity. For instance, one may read about process improvements allowing projects to finish under budget, ostensibly because of increased productivity. This is not *predictability*, it is *productivity* and relatively easy to measure. *Predictability* is the property of being able to estimate how many resources the job will actually require to complete, and consequently how profitable the work will be.

We value predictability because it minimizes *financial risk*,

where financial risk is defined to be *how likely the returns from an investment will be what you are expecting*. A project whose profitability deviates significantly from what was originally expected is less desirable that a project in which the profitability is well known before embarking upon it.

This definition implies that under-predicting (getting more return than you expected) can be as undesirable as over-predicting (getting less return than you expected). This is because we often accept or reject projects based on their expected return. Predictions that under-predict actual returns may result in potentially acceptable projects being rejected, while over-predictions will often result in projects being accepted that should be rejected.

3 PREDICTABILITY AND MATURITY

Data published by Lawlis, Flowe & Thordahl [Lawlis, et.al. 1995] suggests that DoD contractors assessed at higher SEI Maturity Levels did a better job of meeting their target costs. In particular, the ratio of Actual to Budgeted for 17 Level 1 and 17 Level 3 projects suggested that the Level 1 projects exhibited a mean Actual to Budgeted cost ratio of 1.25 with a variability (σ) of 0.63. The Level 3 projects exhibited a mean Actual to Budgeted cost ratio of 1.01 with a variability (σ) of 0.18.

This demonstrates improved predictability by way of reduced variability associated with being a Level 3 vs. a Level 1 project, as is illustrated in Figure 1.

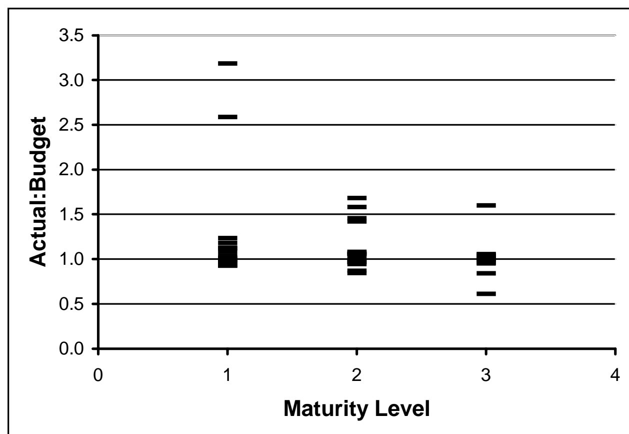

FIGURE 1

4 ASSESSING THE FINANCIAL VALUE OF IMPROVED PREDICTABILITY

The question at hand is how one might go about assessing the value of improved predictions. In order to address this issue, we consider the resources expended in developing a software product as an investment which is used to "purchase" a significant capital asset, which is expected to yield a certain return. The traditional factors that are used to value a financial investment:

- **Returns** - how much do you get?
- **Timing** - when do you get it?
- **Financial Risk** - how likely is it that you really will get what you are expecting?

Net returns are a function of both the cost of development as well as product sales. Obviously both of these may vary. Product costs are controllable by software engineering, while product sales are not. For purposes of this work, we will consider the simplified situation where a software contractor bids on a fixed price project. This has the effect of removing sales variability so we can focus on cost variability.

Timing aspects of an investment are often addressed through the use of Discounted Cash Flow techniques [Brealey & Myers, 2000] such as Net Present Value (NPV). This entails converting monetary returns realized at some point in the future into their present day equivalents. Intuitively this involves computing how much would have to be invested at some predetermined rate of return in order to end up with the same amount of money at the given point in the future. This can be readily computed as:

$$PV = FV/(1+k)^n$$

Where FV represents the expected returns in n periods (Future Value), PV represents the value of that return in today's dollars (Present Value), and k represents the periodic rate of return being hypothesized (the discount rate). The discount rate is usually taken to be the organization's cost of capital. Ordinarily, investment decisions are then predicated upon the Net Present Value (NPV) of the project:

$$NPV = PV_{returns} - PV_{costs}$$

Projects with an NPV greater than zero have a return greater than the discount rate, and should be pursued while projects with a negative NPV should be rejected.

This adequately reflects the effect of time in valuing a return. Given a discount rate k, a rational decision-maker

would be indifferent between receiving the present value (PV) today, or the Future Value (FV) *n* periods on the future. This is because the PV dollars received today could be invested at a compound rate of *k* for *n* periods to end up with the same FV.

However, this does not adequately reflect the impact of risk on an investment. Obviously a more risky investment should be valued at a lower rate than a less risky investment. The predominant investment analysis technique, the Capital Asset Pricing Model (CAPM) [Brealey & Myers, 2000] adjusts discount rates by adding a *risk premium* to the time-based discount rate to reflect the *systematic risk* of an investment.

Traditionally, financial risk is separated into two types: *systematic* and *unsystematic*. Systematic risk represents the risk “inherent in the market”. In traditional investments, this is defined as *the risk of holding the market portfolio.* The way a particular investment behaves relative to “the market” is considered its systematic risk (in CAPM this is known as β). Unsystematic risk reflects “investment specific” return variability, such as unexpected events (natural disasters, catastrophically bad decisions, etc.). Because unsystematic risks can be mitigated by diversification, the main focus tends to be on systematic risk.

It appears that the variation between projections of Level 1 and Level 3 costs are due to systematic effects as opposed to project specific events such as compression of delivery dates or loss of key personnel, etc. This is discussed in more detail in [Harrison & Settle, 2001].

With the addition of a “risk premium” the effective discount rate is comprised of two parts:

$$k = r_f + \phi$$

where r_f represents the “risk free rate” and ϕ represents the risk premium which is assigned due to systematic risk. The risk premium reflects that fact that financial risk is proportional to the relative variability of expected returns. Since product sales are held fixed, this variability is a function of the distribution of expected development costs.

For software projects, the relative systematic financial risk between two projects can be approximated by the ratio of the coefficient of variation for the expected cost of project *i* and project *j*.

$$\lambda_{i\ \mathrm{wrt}\ j} = (\sigma_i/\mu_i)/(\sigma_j/\mu_j)$$

Based on the Lawlis, Flow and Thordahl data, it appears that the relative systematic financial risk with respect to Level 1 and Level 3 projects is approximately 2.83 (Level 1 project projections are 2.83 times more risky that Level 3 projections, or conversely Level 3 projections are 35% as risky as Level 1 projections). Thus, an organization that has in the past required a risk premium ϕ from Level 1 projects should be able to accept a risk premium of 0.35ϕ when deciding upon Level 3 projects.

The benefit accrued from any particular project will be a function of the magnitude of the project (better predictions are worth more in conjunction with larger projects). In order to compute the actual financial value of this increased predictability a project bid, projected project cost, the risk-free discount rate and a baseline risk premium is required.

5 APPLYING THE METHOD

The value of the improved predictability is a function of project size and currently accepted risk premiums. Consequently, there is not a single value or percentage that we can offer to value improved predictability. For illustration purposes, we can consider a pro-forma project that is bid at $7.5M with an expected cost of development of $5M (i.e., an expected profit of $2.5M) and an expected duration of 3 years (which we will assume is certain). Further, the organization has established a risk premium of 5% for projects developed under the Level 1 organization, and uses a 5% risk-free discount rate.

Given these assumptions, the value of the enhanced predictability found in a Level 3 organization can be determined by recognizing that the corresponding risk premium for a Level 3 organizations should be 0.35*5% = 1.75%. Thus, while the Level 1 project would be discounted at 10%, the Level 3 project will be discounted at only 6.75%.

Projects such as this illustrate a series of periods with large cash out-flows followed by a period with a large cash in-flow. For our analysis, we wish to allocate the final period’s cash in-flow across the life of the project in order to associate revenue and cost streams. Thus, the (certain) gross return of $7.5M in 3 years is converted into a

corresponding 3 year annuity at the risk free rate of 5%, resulting in an annualized cash flow of approximately $2,379,442. For simplicity we assume a uniformly distributed annual cost (we are currently investigating patterned annuities and costs that better track earned value) of $1,666,666. This yields an expected return (profit) of $712,776 for each of the three years.

Assuming the Level 1 organization and its corresponding effective discount rate of 10% (5% risk free, plus a risk premium of 5%), the annual Net Present Value for each of the three years for this project is:

Year 1 $712,776 @ 10% = 647,978

Year 2: $712,776 @ 10% = 589,071

Year 3: $712,776 @ 10% = 535,519

For a total Project NPV of $1,772,568.

However, given the reduced risk of the Level 3 organization and the corresponding reduced risk premium. The annual Net Present Value for each of the three years is:

Year 1 $712,776 @ 6.75% = 667,705

Year 2: $712,776 @ 6.75% = 625,242

Year 3: $712,776 @ 6.75% = 584,242

For a total Project NPV of $1,877,189, a difference of $104,621.

The total Project NPV is significant because it represents the contribution of the project to the value of the firm (or at least the contribution of the portion of the project yet to be completed). Consequently, a project such as this that enjoys reduced variability in forecasting contributes over $100,000 more value to the organization than does the more volatile project.

Of course, for a more realistic picture of the value of enhanced predictability, such an analysis must be made over an entire portfolio of projects that are affected by the pursuit of process improvement. Further, we certainly cannot ignore the contribution of reduced rework and increased productivity that was mentioned earlier when assessing the value of process improvement. But at the same time, as we have shown, the value of improved predictability can also have a non-trivial impact on the Return on Investment of process improvement.

6 SUMMARY

We have proposed a technique by which the financial value of improved predictability based on process improvement can be determined. This approach uses a variation of the Capital Asset Pricing Model (CAPM) to assign a risk-adjusted discount rate for NPV calculations. The ultimate value of the improved predictability gained by process improvement is the difference between the Net Present Values of the project with and without the benefits of process improvement.

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