2000

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Abstract

The SA-CMM is based on the expectation that a mature organization and its project managers will do a thorough job of planning software acquisitions. Each key process area within the SA-CMM addresses a project management process that must take place as an adjunct to planning and managing the software acquisition project. This requires the allocation of resources to plan and oversee the acquisition activities. While software project cost estimation tools are becoming more precise in their ability to predict the costs associated with software production, few address the costs associated with acquisition planning, oversight and management. Such costs are considered "hidden."

This paper describes a methodology used and the research done to determine the effort expended by organizations in overseeing software acquisitions and the implications for predicting costs of proposed projects. A major goal of the research was to encourage a quantitative approach in collecting acquisition costs within an organization so that databases of completed projects can be used to forecast costs for future projects. Such a quantitative approach helps identify the true cost of the project which is essential to economic analysis techniques used in the decision making process for software projects.

Although both the CMM and SA-CMM were used in the research as frameworks to assess software management processes, the SA-CMM was primarily used for assessing the acquisition processes and measuring their costs.

Background: SA-CMM Issues

The Software Acquisition Capability Maturity Model (SA-CMM) is a process improvement framework based on the key practices of organizations that acquire software systems and products. It is a model that describes the key elements of managing and improving the acquisition process in an organization. The SA-CMM outlines a managed path for improving the processes for acquiring software - from an ad hoc undisciplined approach to a mature, disciplined approach in which all aspects of the acquisition and oversight processes are managed to enhance the organization's overall performance of work.

SA-CMM defines five levels of organizational maturity in software acquisition:

- Initial (Level 1) - few acquisition management processes are formalized or defined, success relies on the competence and the heroic efforts of individuals.
- Repeatable (Level 2) - the focus of this level is on basic acquisition project management. The process capability of Level 2 acquisition organizations can be summarized as being stable for planning and tracking the software acquisition because documented procedures provide a project environment for repeating earlier successes. All members of the team are committed to complying with project plans, required policies, regulations, and standards. Project managers track costs, schedules, requirements, and performance of the project. The key process areas for this level are:
  - Software Acquisition Planning
  - Solicitation
  - Requirements Development and Management
  - Project Management
  - Contract Tracking and Oversight
  - Evaluation
  - Transition to Support
- Defined (Level 3) - the organization has an integrated set of software processes that are documented and standardized and those processes are applied across the organization. The Software Process Capability of Level 3 organizations can be summarized as standard and consistent because acquisition management activities are stable and repeatable. The key process areas are:
  - Contract Performance Management
  - Project Performance Management
- Managed (Level 4) - the organization maintains a software process database to record, manage, and analyze quantitative data about the organization's processes and projects. Because processes and projects are measured, the organization's performance is quantifiable and predictable. The key process areas are:

  - Quantitative Acquisition Management
  - Quantitative Process Management
- Optimizing (Level 5) - at the Optimizing Level, the entire organization is focused on continuous process improvement. The key process areas are :
  - Acquisition Innovation Management
  - Continuous Process Improvement

The SA-CMM specifies activities to be performed by acquiring organizations for each of the key process areas for each maturity level. An organization operating at maturity Level 2 or higher has activities in place that specifically address the planning and management of acquisitions. Examples of tasks supervised by the project manager are tracking costs, schedules, requirements, and performance of the project. Problems in meeting commitments are identified when they arise. Software requirements are base-lined and the content is controlled. Software documentation is evaluated for compliance with specified requirements. Project teams work with their prime contractors, and any subcontractors, to establish a stable, cooperative working environment. Project teams track the performance of the contractor for adherence with project plans and for ensuring that contractual requirements are being satisfied. Solicitation involves planning and performing the activities necessary to issue the solicitation package, preparing for the evaluation of responses, conducting the evaluation, conducting negotiations, and awarding the contract. As the organization moves to a higher maturity level, more time consuming tasks have to be performed by the acquiring organization personnel. This research identified such tasks for each key process area of the SA-CMM and developed a template that was used for cost data collection.

Project Cost Estimation

Traditional and evolving software estimation methods and tools focus primarily on the technical resources needed for developing a software product. Few cost estimation tools address the costs associated with users' involvement during the project lifecycle. And, when an organization is contracting for software, the procurement process, subcontractor oversight and management costs are rarely considered. Since such costs can be significant, they should be included as part of the cost of subcontracting and should be part of software cost estimation models used to predict project costs.

Organization's are motivated to perform software cost estimates for the following primary reasons:

- Project approval. The role of cost estimation is vital to any decision that is based on an economic feasibility and analysis. Before undertaking a software project, a decision by the organization management has to be made. Such a decision is usually based on an economic analysis, which requires an estimate of the money, resources and time required to complete the project. The role of cost estimation is vital to such analysis as it is impossible to perform cost benefit analysis, breakeven analysis or make-buy decisions without a formal method for estimating software costs and their sensitivity to various product, project and organizational factors.
- Project management. Cost estimation provides a basis for effective project management in planning and control of projects. Good planning and effective control require an estimate of the activities required to complete a project, and the resources required for each activity for monitoring progress. Without reasonable and accurate cost estimation, projects can experience budget overruns, unrealistic schedules and quality compromises due to optimistic promises and a desire to win a contract. The relationship between cost estimation and controlling projects are detailed further in (DeMarco, 1982).
- Project team understanding and reporting. For members of a project team to work together efficiently on a project, it is necessary that each member understand his/her role in the project and the overall activities of the project. Project members can also monitor their own progress and provide better reporting on the status of project tasks to management. A project task definition, which can be used for this purpose, is generated by a cost estimate.

Of course, mature organizations extend the cost estimation activity as a metrics gathering and analysis exercise to improve the accuracy of estimates and improve the life-cycle processes.

Project Cost Research

This paper addresses the improvement of cost estimation processes for forecasting and controlling development costs by procuring organizations. The goal of the supporting research was to improve the process of cost estimation by revealing the hidden costs of software development for a contracting organization. This research used the SA-CMM framework to identify such costs, and developed a template measuring them relative to the project cost. The research addressed also the consequences to the organization for failing to recognize the hidden costs. At a minimum, failure to plan for contracting costs introduces risks to projects and greater costs in the long term to mitigate the risks. The goal of the study was to contribute to the refinement of the available software estimation models by examining the procuring organization user and management costs that ordinarily are not factored into the total system cost. Another goal of the research was to encourage the collection of data about contracting costs within an organization so that

databases of completed projects can be used to forecast costs for future projects.

In surveying companies about their acquisition practices and the collection of acquisition costs, a questionnaire was prepared and distributed. The portion of the questionnaire that was used to collect costs used the SA-CMM key process areas to identify the practices of the organization and as a basis of cost data collection. In some cases, the target-organization returned the completed survey, in other cases, face-to-face interviews were carried out using the questionnaire as an interview instrument. The research questions were modeled after the format of the CMM which uses similar questions to evaluate the maturity of the processes and the capability of organizations. The CMM specifies that the lack of formalized and documented procedures is an indication of a low maturity level and immature processes. These concepts were applied in the study to test the cost estimation processes of organizations in the sample.

The strategy used to discern and evaluate hidden contracting costs included the following:

- Determine whether the contracting (acquiring) organization has processes in place for estimating resources for software projects.
- Determine whether expended resources on contracted projects were estimated, planned, and tracked.
- Determine whether historical data is collected on contracted project costs.
- Determine whether historical data about software contracts is used in economic analysis of projects.
- Determine whether contracting organizations track user and management expenditures according to project lifecycle phase.
- Determine which organizational resources actually participate in contracting.
- Determine the effort expended by the contracting organizations on the projects surveyed.
- Determine characteristics of contracted projects in terms of size and complexity.
- Determine the cost drivers that influenced hidden costs.
- Determine impact on the organization of hidden contracting costs.

Results of Survey

The survey questions were designed with the intent of determining whether procuring organizations have formal processes for the estimation of their resources involved in contracted software projects. Are there costs incurred by such organizations that are not accounted for in the project budget that can be considered hidden? Is this cost included in any economic analysis or feasibility of the project?

Absence of Estimation Processes. From the study, we determined that the majority of contracting organizations:

- Do not formally estimate and plan their resources, including project management, users, quality assurance, consultants (other than contractors), and others working on software development projects.
- Do not have standard procedures or formal processes for planning and scheduling of their resources on software projects.
- Do not have formal procedures to collect historical data on their resources that were involved in software projects.
- Do not include the cost of their resources that were involved in a software project in the total project cost.
- Do not include cost of their resources in any economic analysis or feasibility of the project.

Other specific conclusions drawn from this study included: a majority (88%) of the organizations did not estimate their resources on completed projects, a majority (65%), do not have formal processes to estimate, plan and schedule such resources. Management resources, which are critical for project oversight, are more likely than other resources to be planned by organizations, but still are not planned by 69% of organizations. User resources, whose involvement in the project is considered critical, are not planned by 92% of organizations. The study showed that the users and management resources constitute the highest percentage of the hidden cost, yet they are not planned by the majority of contracting organizations. The lack of formal processes for planning resources, introduces risks to the project as some of the critical resources are not committed formally to the project and might not be available when needed, in particular those of management and the users. (Jones, 1994) and (Statz and Tennisson, 1995) point to the risks that can be introduced to the project by not managing such resources. organizations, the source of funding of project management, users, quality assurance, consultants (other than contractors) and other resources working on software development projects, is not the project budget. The costs of their resources including project management, users, quality assurance, consultants (other than the contractors), and others working on software development projects are not included in the project cost -- the costs of the resources are indeed hidden. For the majority of organizations, the study finds that the costs of project management, users, quality assurance, consultants, and others working on software development projects are incurred, but are not estimated or planned. Such costs are unmeasured, and are not included in the final project cost.

Distributions of Hidden Costs. Research questions related to the measurement of the hidden cost were intended to determine the percentage of the total effort expended by the contracting organization personnel

including management, users, quality assurance, consultants and others, expressed in man-months, of the total development effort. What is the distribution of effort in the various phases of the development lifecycle? What is the distribution of the effort for the various resource categories and other resources over the lifecycle?

By examining the hidden cost phase distribution, we find that analysis and implementation constitute the largest percentages followed by the testing phase. Analysis is considered one of the most risk prone activities, one in which the user is heavily involved. The role of the user is also important during the testing of the software product for acceptance and the implementation when the product is put into operation. The results of the distribution of the hidden cost by labor categories show that the users and the project managers resources are the most significant. This result is important in the sense that it draws attention to the need to plan and schedule these resources. The distribution of the hidden costs by labor category and by phase draws the attention to the various needed resources and when they should be planned and scheduled during the various phases of the software project along with their proportions. The results of the study concerning the user and management resources needed complements and supports results of other studies. For example, a recurring theme in risk studies, such as (Statz and Tennisson, 1995), is that user participation, customer and user interaction, and user resource allocation, are sources of risks that need to be assessed and managed. Also, risk studies by (Jones, 1996) point to the importance of project management activities. Project management is considered by (Jones, 1996) to be one of the key factors for the success of systems. The general conclusions that we can make based on these results is that the hidden costs are substantial, and the needed resources must be planned, scheduled and better managed during the points in the lifecycle when their participation is critical.

Hidden Costs and Project Size

Another survey focus addressed whether there are any relationships between the hidden costs and project size. And, which project attributes are significant and constitute the cost drivers that influence the cost of the contracting organization in the development of software systems?

The significant positive relationship between the hidden cost and the project size expressed in lines of code is an important result of the study. The prototype model depicted the relationship between the hidden cost and the product size expressed in thousands lines as follows:

MM=3.2*KLOC+.19 (All data points)
MM=2.2*KLOC+51.9 (No outliers)

where, MM is the contracting organization's hidden cost expressed in man-months and KLOC is the software product size in thousands lines of code. The second equation with, no outliers, is a better reflection of the hidden cost as it shows the up-front cost of a software project. Before any lines of codes are written, costs are incurred due to the acquisition process. In other words when KLOC is zero, there is a value for the hidden cost shown in the above equation to be approximately 52 man-months. The prototype linear model developed, where the independent variable is the number of lines of code, is very significant because most estimating methods use lines of code as the major cost predictor of technical resources needed for the development of the software. These results can be incorporated into current cost estimation methods and tools, by including the contracting organization user and management costs, thereby enhancing the accuracy of methods used for software projects cost estimation and improving the predictability of all costs. They also provide background information and a starting point for organizations to develop their own customized cost model.

Conclusions

This paper addresses the improvement of cost estimation processes for forecasting and controlling development costs by procuring organizations by identifying additional factors affecting the cost of a software system, providing a formal methodology and a model to improve the cost estimation process and a means of measuring it. The research done also encourages the collection of data about contracting costs within an organization so that databases of completed projects can be built and later used to forecast costs for future projects. Such an approach is recommended by process improvement organizations and initiatives such as the CMM and SA-CMM, which require an organization to have a formal technique for cost estimation in place before moving to higher maturity levels. This focus is likely to improve overall software development processes and the decision making in the procurement of software systems. Despite this emphasis, few organizations keep detailed data that isolates hidden user and acquisition management costs.

For many of the organizations that participated in the survey, realizing the actual cost of a project was an eye opener. The following are quotes from participants in the survey:

"Failure to include the oversight cost in original estimates can result in having to forego oversight activity to the detriment of the project. It can also result in embarrassment when the true cost of the project becomes apparent."

"This work is very important. I would like to have a copy of the results when they are available to encourage more organizations to plan for all that is necessary to make a project successful and optimize business resources who have the critical knowledge the business needs to get into their systems."

The results of this research are important to contracting organizations -- hidden costs are incurred, the costs are significant, and they are typically not managed. Failure to plan and schedule critical resources such as users, project managers, domain experts, management software, and other resources may pose a risk to a contracting organization and to the project itself. Organizations that understand the inherent costs of contracting software are better positioned to estimate costs of future projects and also improve decision-making process

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