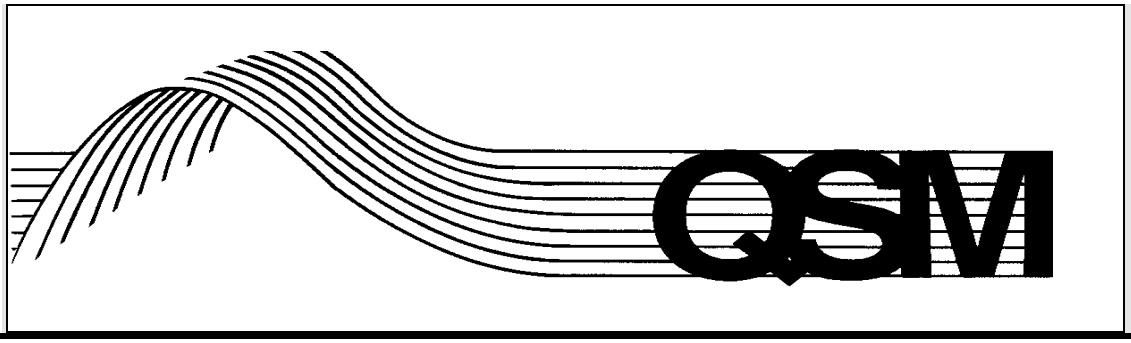

MEASURES FOR EXCELLENCE

Measures

For

Software

Acquisition

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Introduction

"Improved cost information needed to make billion dollar modernization investment decisions" is the title of a report identifying the problems faced by a major purchasing organization. The cost information relates to software development; the organization is the Federal Aviation Authority (FAA) in the United States (US).

The report (Ref.1) by the US General Accounting Office (GAO) highlights the shortcomings found when they assessed the FAA software dependent system procurements. The Software Engineering Institute (SEI) maturity requirements (Ref. 2) are used to identify the capability of the FAA to acquire software based Air Traffic Control (ATC) systems.

The situation revealed in the GAO report is found in many organizations that purchase high technology systems with a software development content. Such acquisitions are notorious for time overruns, cost escalation, reduced functionality, poor quality, legal disputes and can result in projects being abandoned. Examples are to be found in many areas including Telecommunications, Defense, Process Control, Avionics, Space and Business Systems.

The SEI requirements are used to evaluate the FAA acquisition capability and apply equally in all major purchasing groups who deal with proposals that involve software development. The requirements and the findings as set out in the report relate to the FAA capability to manage software acquisition and are summarized as follows:

SEI Requirement	**FAA Policies and Practices**
• Corporate Memory	No
• Sizing and Reuse	No
• Extrapolation using actual performance	No
• Audit Trails	Partial
• Integrity within dictated limits	No
• Data collection and feedback on actual performance	No

The evaluation using these criteria set out in the report reveals that the FAA is at a serious disadvantage in dealing with suppliers. As the report summarizes:

"Weak cost estimating practices undermine the FAA's ability to make informed investment decisions".

Meeting the Requirements

In this paper we set out how these SEI requirements are successfully addressed using proven management methods designed for software acquisition. These methods are based on practical experience using the quantified analysis provided by Quantitative Software Management (QSM).

To meet the requirements calls for a quantified approach that enables:

- each vendor's development capability and their software bids to be measured and compared
- all proposed software to be sized to provide clear visibility of what must be developed, identify re-use and manage growth
- the value for money and risk in each development proposal to be determined
- a quantified baseline to be established as the basis for tracking progress and controlling all changes for each development after contract award
- mandatory data to be supplied during development to assess progress against the contract baseline limits
- identification of potential slippage, cost overrun and defects during development to provide forecasting based on progress to date
- the recording of all plans and forecasts as an audit trail for the development history
- the building of a repository of development history to provide reference measures and rank vendor's process productivity and quality

Practical acquisition management methods are introduced in order to achieve these goals. These methods make use of quantified information regarding vendors, their bids, the subsequent development progress and specific acceptance criteria related to reliability. Two key methods are used: 1) Software Tender Evaluation and 2) Development Control. An overview is given of the QSM software management measures and their use in support of each of these methods. A final section sets out results achieved with two major purchasing organizations.

QSM Software Management Measures

The analysis of actual data from a large number of software projects by QSM (Ref. 3) shows that the relationship between three major drivers determines the time and effort to develop software as well as the defects. The three drivers are:

1. The amount of software: hence it is essential to quantify the size of the software proposed including uncertainty and monitor any changes during development.

2. The process productivity of the vendor development environment. This measure reflects the factors unique to each vendor and is calculated by collecting simple data from past projects.
3. The time planned for development and hence the peak staffing. Simply put the more people who work on the development, the sooner the software is developed

but with greatly increased cost. Our findings show that larger teams deliver poorer quality (more defects) in the software product.

QSM model these drivers in a way that enables each to be expressed in management terms and reveals the impact that each has on software development.

For instance our findings show that a low process productivity and short time scale (namely a poor development process and lots of people) increases the defect creation process at an accelerating rate.

QSM Software Tender Evaluation Method

Figure 1 sets out the steps in the QSM Software Tender Evaluation Method. In Step 1 the purchasing organization makes an independent "should cost" estimate of the likely time, effort and reliability. This capability improves as a repository of vendor performance is built. A common software acquisition questionnaire is used in Step 2 (Ref. 4) and adapted to each Invitation To Tender (ITT).

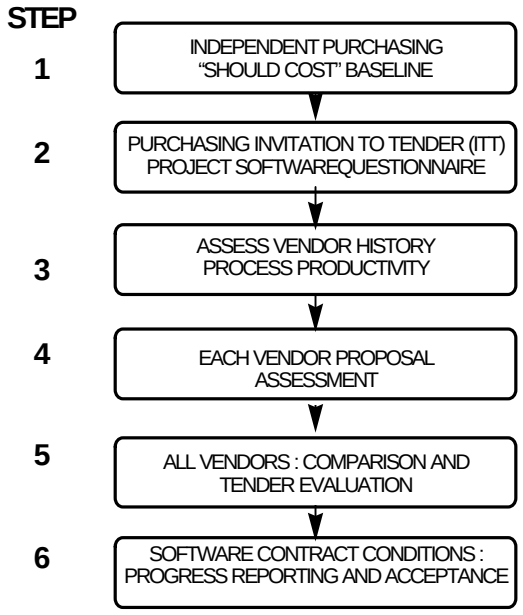

Figure 1: QSM Software Tender Evaluation Method (TEM)

The questionnaire requires each vendor to give data on completed projects as well as the proposed plan for the new development that includes sizing the proposed software.

Selecting the winning vendor is based on measuring performance in completed projects, evaluating the detailed sizing of the software, including uncertainty and re-use, to confirm the development proposal time and effort is consistent with their history and QSM reference measures (Steps 4 and 5).

The winning contract is let (Step 6) against an agreed baseline and formal progress reporting requirements. The formal progress reporting data is used to track progress against the established baseline and is used in the control function described next. Criteria are defined for acceptance and include a specified mean time to failure.

Software Development Control

We find that purchasing organizations benefit from introducing a control office function (Ref. 5) dealing specifically with software contracts. This function is responsible for assisting with the tender evaluation as described above and then monitors and reports on all on-going developments, typically each month. To monitor progress each contractor is required to return high-level progress data every two weeks or every month. This data is defined and made mandatory as part of the contract.

The activities performed by the control office for the in-progress developments are shown in Figure 2 and are described next.

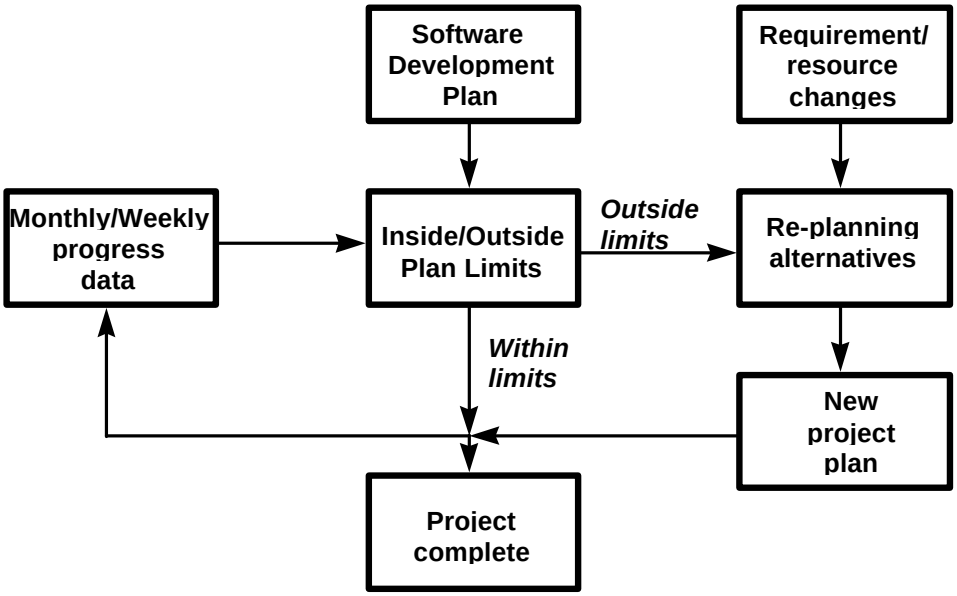

Figure 2: QSM Software Development Control Method (DCM)

The software development plan is established formally when the contract is awarded. This high level plan sets out the time, staffing and effort for each development phase as well as the software size and uncertainty. Major milestones form part of the plan together with agreed measures dealing with incremental developments and test plans.

A key part of the plan defines the mean time to failure required before acceptance of the software. Payment is linked to achieving this milestone.

The contractor returns the progress data agreed in the contract. Failure to supply the data or supply incomplete data results in penalties. The progress data is logged against the contract baseline plan and every two weeks or each month any variation determined. If inside the established limits this situation is reported by the control office as being according to plan.

If the data reveals the progress is outside the agreed limits then an evaluation of re-planning alternatives is made. In addition the project is classified as being at risk and the control office function notifies the parties involved and takes action to reduce the risk to the development.

As a result of detecting slippage, a new project plan may be required that recognizes the current position and actions agreed to reduce the overrun. For instance additional time and effort are planned or more staff added. In major projects there are frequent requirement changes. These can be assessed against the current position in the development to decide whether to include the changes in the current development or postpone to the next release.

By collecting the progress data throughout the development a complete history exists on completion of the project. This history is stored in the repository containing data on vendors and their capabilities. A review is held to learn the lessons from the development and the insights these provide in to the purchasing organisation operation and the contractor performance.

Meeting the SEI Requirements

Purchasing managers are able to meet the SEI requirements by implementing the methods outlined above. Next we summarize the main capabilities the methods provide to meet these requirements.

- **Corporate Memory:** Using the questionnaire measures are made on vendors past projects, compared to the new proposal and details preserved on the agreed contract baseline. During implementation all details are kept of progress, new forecasts, changes to plans and the final process productivity achieved by the contractor.

- **Sizing and Reuse:** The formal evaluation requires each vendor to size all software including uncertainty and re-use. One use is to quantify the assumed process productivity and risk in the software implementation plan. Subsequently the contract baseline size is used to track progress in each software module, negotiate requirement changes and, on completion, a record exists of the final size and amount of re-use.

- **Extrapolation using actual performance:** Basic progress data is used during implementation with the agreed contract baseline and uncertainty to determine if progress is within agreed limits. If progress is found to be outside the limits then new forecasts are made of the outstanding time, effort, cost, defects and actual process productivity.

- **Audit Trails:** The initial baseline plan proposed by each vendor is recorded together with potential alternatives. During implementation all progress data, new forecasts and agreed contractor plan revisions are recorded. This includes the size and impact of requirement changes.

- **Integrity within dictated limits:** Each vendor proposal is evaluated against stated acquisition constraints of time, effort, cost, reliability and risk. During implementation progress is regularly reviewed to confirm it is within the contract limits.

- **Data collection and performance feedback:** The methods capture the complete history of the development including initial proposals, the contract baseline, progress data, forecasts and revised plans. This information is used to continuously update the data repository of vendor performance and highlight those vendors who provide value for money.

Results

Two purchasing groups provide published results from using the QSM techniques.

The first results are set out in a paper authored by the control office manager of the PTT Teleco BV Netherlands (KPN) Logistics group (Ref. 6). The management focus within the Logistics Purchasing group is through their control office function. The paper describes the results from applying the methods to deal with the acquisition of a wide variety of high technology telecommunication and business systems over five years:

“We learned that metric discussions should be directed to three points—

- Understanding the project better;
- Controlling it better, and
- Increasing its visibility to upper management.

We expect suppliers to run their own businesses in their own way. We just ask for the data we need. It is their business to figure out how to provide it. If they cannot structure their process to provide it then it is then our business to move to another supplier.

We learned not to track chaos. Sometimes suppliers have fancy terms for their chaos—incremental, parallel or timebox development, for instance, or rapid application development or prototyping. Also, there is a difference between chaos and “good enough” data. We learned that you do not always need precise numbers so long as you

are close enough! Some level of uncertainty, especially in early stages of the project, is nothing to be ashamed off. But it is assumptions that pave the road to failure.

On a more mundane level, we learned:

1. Metrics enabled us to focus discussions with suppliers;
2. Negotiations were more to the point, their outcome more successful;
3. Metric traffic lights drew management attention to marginal projects;
4. Metric analysis established its predictive value by its proven record within the PTT;
5. More projects were delivered within budget, on time, with an acceptable quality level;

Metric analysis is not only a management tool;
it is a management philosophy."

Our second reference is a relatively new user of the QSM Tender Evaluation Method, Railtrack, responsible for the railway infrastructure in the UK (Ref. 7). Here the QSM method is used to assess proposals to develop a real-time train location database updated by GPS and public mobile telephone network. Comments from Railtrack include:

"It was easy to see which proposals could be substantiated using the reference projects. Having a quantitative calibration of performance really helped us decide which tenderers could be relied on and which were high risk.

What's more, the QSM analysis was a potent tool for exposing inconsistencies or uncertainties in the proposals. We were able to challenge parts of the plan and clarify technical and management issues, to the benefit of both Railtrack and the winning supplier.

I know there are other developments that can really benefit from this type of expert advice"

Ref.1. GAO Report to the Secretary of Transportation: Air Traffic Control GAO/AIMD-97-20
Ref.2 A Managers Checklist for Validating Software Cost and Schedule Estimates (CM/SEI-95-SR-004)
Ref.3 For further information on QSM's practices, refer to Lawrence H. Putnam and Ware Myers, *Industrial Strength Software: Effective Management Using Measurement,* IEEE Computer Society Press, Los Alamitos, CA, 1997, 309 pp.
Ref.4 KPN PTT Logistics Software Development questionnaire version 5: Software Control Department
Ref.5 The Software Control Office J.W.E. Greene, EC2 Software Engineering Conference Toulouse 1990
Ref.6 G.W. Kempff Software Control Office Manager PTT Telecom BV Netherlands Draft paper Managing Software Acquisition
Ref. 7 QSM Perspectives Autumn 1997.