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PROPOSED CONCEPTS FOR A TOOL FOR MULTIDIMENSIONAL PERFORMANCE MODELING IN SOFTWARE ENGINEERING MANAGEMENT

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***Abstract* – A major difficulty with current organizational performance models in software engineering management is to represent many possible viewpoints quantitatively and in a consolidated manner, while at the same time keeping track of the values of the individual dimensions of performance. The models currently proposed do not meet the analytical requirements of software engineering management when various viewpoints must be taken into account concurrently.**

This paper presents a selection of multidimensional models of performance in software engineering and in management. It then describes the proposed concepts for a tool for multidimensional performance modeling in software engineering management. The tool would adopt an organizational framework of performance and build upon an open, generic and geometrical approach to performance modeling called QEST. It would also enable the user to select different visualization techniques to analyze data. In addition, the proposed tool would allow the user to iteratively define, collect and analyze multidimensional measures at each life cycle phase, and even enter potential results for subsequent phases. The initial test bed of the proposed tool would be the repository of project data of the International Software Benchmarking Standards Group (ISBSG).

***Keywords:* Performance modeling, Multidimensional management models, Visualization, Software engineering management, International Software Benchmarking Standards Group, ISBSG, QEST**

I. INTRODUCTION

A major difficulty with current performance models in software engineering management is to represent many possible viewpoints quantitatively and in a consolidated manner, while at the same time keeping track of the values of the individual dimensions of performance. "Performance" in this paper means the performance of a software engineering organization, rather than that of software or hardware.

There already exist a significant number of one-dimensional models of performance which integrate individual measurements into a single performance index. These models can be found in software engineering management [1], as well as in other disciplines. However, these models do not meet the analytical requirements of software engineering management when various viewpoints must be taken into account concurrently.

Modeling of various viewpoints and doing so at different levels of abstraction is widely practiced in software engineering, especially in software design. It is therefore seen as key to software engineering, in particular because of the intangibility and complexity of software. However, modeling is much less widely practiced in software engineering management, except for the usual Gantt and Pert charts and work breakdown structures.

The next section of this paper presents a selection of multidimensional models of performance in software engineering and in management. Section II describes the proposed concepts for a tool for multidimensional performance modeling in software engineering management which would adopt the organizational framework of performance of Sink and Tuttle [2, 3] and build upon an open, generic and geometrical approach to performance modeling called QEST [4-7]. It would also enable the user to select different visualization techniques to analyze data. In addition, the proposed tool would allow the user to iteratively define, collect and analyze multidimensional measures at each life cycle phase, and even enter potential results for subsequent phases. The initial test bed of the proposed tool would be the repository of project data of the International Software Benchmarking Standards Group (ISBSG) [8]. A brief summary concludes the paper.

II. A SELECTION OF MULTIDIMENSIONAL PERFORMANCE MODELS

This section presents a selection of multidimensional performance models found in the literature. The first subsection discusses multidimensional models of software quality and of performance found in the software engineering literature in particular. The next subsection presents generic multidimensional performance models. The subset of multidimensional performance models selected for this section was chosen because its models were deemed to be representative of the wider set of models found in the literature and because of the possibility of applying elements of the selected models in the tool proposed in the next section.

A. MULTIDIMENSIONAL MODELS OF SOFTWARE PERFORMANCE AND SOFTWARE QUALITY

The quality model defined in ISO/IEC 9126 [9], recognizes three aspects of software quality, as shown in Figure 1, and defines them as follows:

- Quality in use, which is the user's view of the software product when it is used in a specific environment and in a specific context. It measures the extent to which users can achieve their goals in a particular environment, rather than measuring the properties of the software itself.

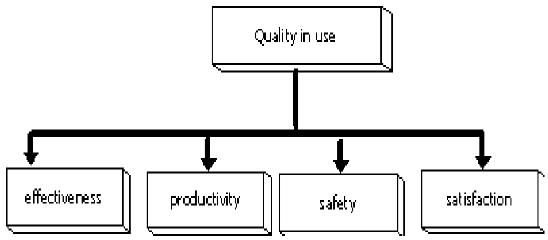

Figure 1 Quality in use model (Adapted from [9])

- External quality, which is the totality of characteristics of the software product from an external viewpoint. It is the quality we look for when the software is executed.
- Internal quality, which is the quality of characteristics of the software product from an internal viewpoint. Internal quality is measured and evaluated against requirements.

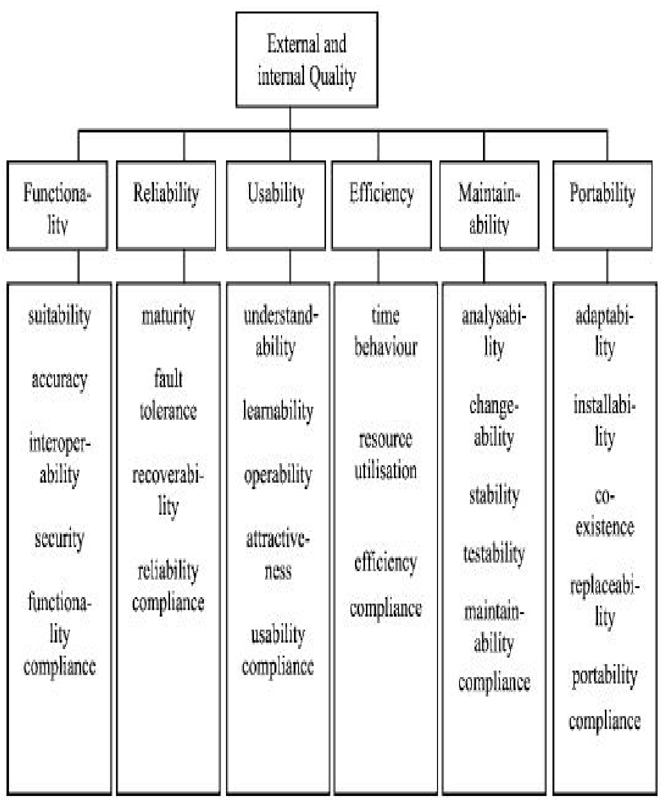

Figure 2 The ISO 9126 model of internal and external quality [10]

The ISO model is generic and can be applied to any software product by tailoring it to a specific purpose. The high-level internal and external quality characteristics shown in Figure 2 are assumed to be independent of one another.

The Balanced IT Scorecard (BITS) [11, 12] proposed by the European Software Institute (ESI) is a specific version of the four original perspectives for the software engineering sector[1] of the Balanced Scorecard (BSC) presented by Kaplan and Norton: financial, customer, internal process, infrastructure and innovation, and adds a fifth, the people perspective. BITS supports identification and prioritization of software process improvement needs from business goals, agreement on, and communication of, the business strategy, identification of the critical set of factors affecting business goals and selection of the minimum set of indicators required to monitor the performance of software processes.

The QEST (Quality factor + Economic, Social and Technical dimensions) model is capable of handling independent sets of dimensions without predefined ratios and weights. The three dimensions taken into consideration, as shown in Figure 3, are combined through the use of a regular geometrical representation of a pyramid (tetrahedron), the sides of which represent the normalized values of each of the software engineering project dimensions being measured. The apex of the tetrahedron represents the performance target. With this 3D representation, it is possible to determine and represent performance considering the usual and distinct geometrical concepts of distance, area and volume. Several papers cover different aspects of the QEST Model: the theoretical aspects [13], the geometrical and statistical foundations of the model [6] and the implementation of the model [7]. An extension of the QEST model to *n* possible dimensions [4], called QEST nD, targets complex software projects when a greater number of dimensions must be taken into account.

The overall project performance (*p*), as shown in Figure 3, is determined using the corresponding classic geometrical formulae, such as the volume of a truncated tetrahedron defined by the individual perspective values (*Qe*, *Qs* and *Qt*) divided by the total volume of the tetrahedron. The three initial perspectives are: economic, social and technical (*E*, *S, T*).

The LIME (LIfe cycle MEasurement) model [13] extends the QEST model concepts to a dynamic context, and can be applicable to each step of any topology of SLC (software life cycle) selected. The LIME model considers a generic 6-phase waterfall SLC structure.

The iterative definition, collection and analysis of multidimensional measures at each life cycle phase offer the possibility of making adjustments for the next phase, as well as for designing improvements.

[1] See next subsection.

The QEST model also produces a unitary performance indicator. The change of a value in one of the viewpoints implies a translation of the hyperplane for all the other (n-1) points.

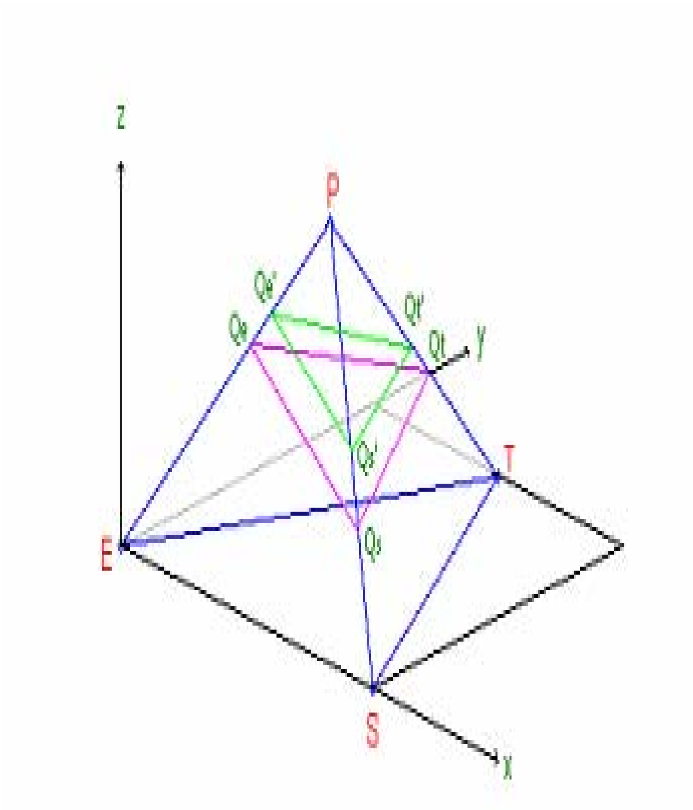

Figure 3 The QEST Model [5, 7]

B. GENERIC QUALITY AND PERFORMANCE MANAGEMENT FRAMEWORKS

Sink and Tuttle argue that the performance of an organization is a complex interrelationship between seven criteria [2, 3], as shown in Figure 4:

1. Effectiveness is expressed as the ratio of actual output to expected output;
2. Efficiency is defined as the ratio of resources expected to be consumed to resources actually consumed;
3. Quality represents the quality criterion at the position in the systems model where it must be operationally defined, measured and managed; quality being a critical criterion at all stages of the life cycle of an organizational system;
4. Productivity is defined as the ratio of output to input,productivity being viewed has having the strongest impact on performance, as well as giving insight into effectiveness, efficiency and quality.
5. Quality of work life is an essential contribution to a system which performs well, quality of work life moderating the equation between productivity and profitability. Poor results in this area usually spell failure for an organization in the long term.
6. Innovation is the creative process of successfully changing whatever it takes to survive and grow; it also moderates the equation between productivity and profitability. Poor results in this area may also mean failure for an organization in the long term.
7. Profitability represents the ultimate goal for any organization except. For non-profit organizations this criteria could be "budgetability" rather than profitability.

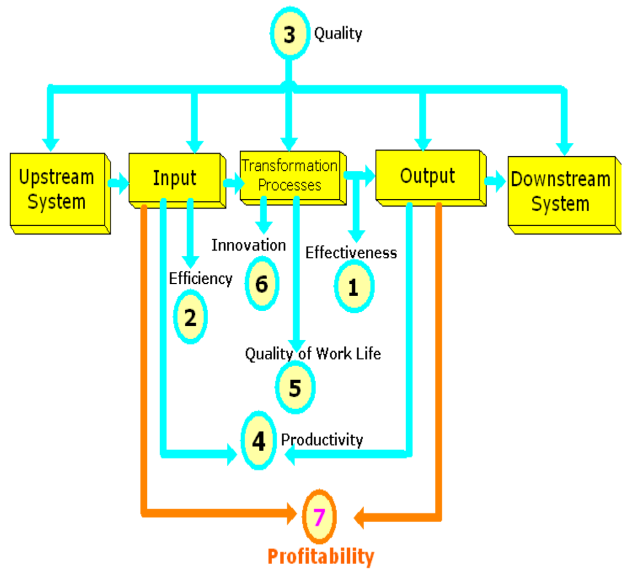

Figure 4 Sink and Tuttle Performance Criteria [2, 3]

Sink and Tuttle describe measurement as being critical to performance management and an integral part of each step of the performance improvement planning process. Using measures to improve performance and build a commonly accepted vision regarding where and how performance needs to be improved will overcome fear of measurement. The performance management process must manage what gets done and how it gets done [2, 3].

It was in response to the shortcomings of traditional accounting data for performance evaluation, that the multidimensional performance model (BSC model) was developed in 1992 [14-16]. The initial BSC model is used to evaluate corporate performance from four different perspectives: the financial perspective, the internal business process perspective, the customer perspective, and the innovation and learning perspective.

Kaplan and Norton argue that "*the four perspectives should be considered as a template […], not a straight jacket. No mathematical theorem exists that four perspectives are necessary and sufficient. There are companies using fewer than these four perspectives, but, depending on industry circumstances and a business unit's strategy, one or more additional perspectives may be needed*" [15]. Based on the

Kaplan and Norton framework [14, 16], a performance model can be built, like the one shown in Figure 5.

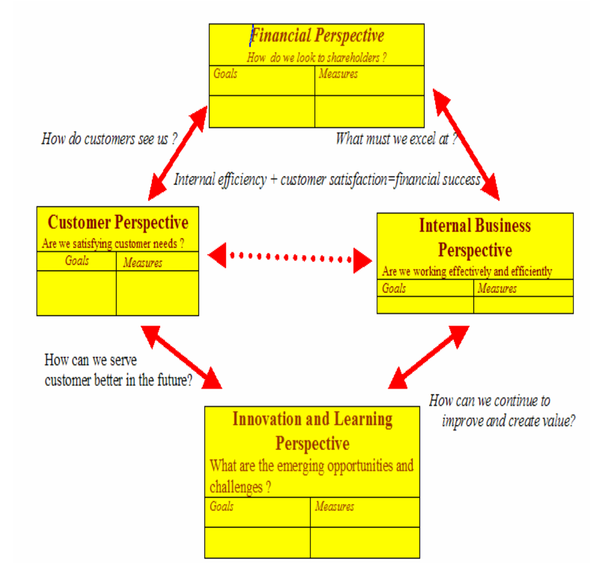

Figure 5 Relationship between four perspectives [14]

The BSC methodology has notably received increased attention in Japan [17]. The four BSC perspectives of Kansai Electric Power are: the strategy map, strategic communication, strategy focus and change in the organizational climate.

The Baldrige award [18] provides a full framework that any organization can use to improve overall performance. Its framework is composed of seven criteria:

- Leadership: Examines how senior executives guide the organization and how the organization addresses its responsibilities;
- Strategic planning: Examines how the organization sets strategic directions and how it determines key action plans;
- Customer and market focus: Examines how the organization determines the requirements and expectations of customers and markets; builds relationships with customers; and acquires, satisfies, and retains customers;
- Measurement, analysis and knowledge management: Examines the management, effective use, analysis, and improvement of data and information to support key organization processes and the organization's performance management system;
- Human resource focus: Examines how the organization enables its workforce to develop its full potential and how the workforce is aligned with the organization's objectives;
- Process management: Examines aspects of how key production/delivery and support processes are designed, managed and improved;
- Business results: Examines the organization's performance and improvement in its key business areas.

The European Foundation for Quality Management (EFQM) Excellence Model [19] is a non-prescriptive self-assessment approach developed as a framework for assessing applications for the European Quality Award. It uses nine criteria, covering leadership, policy and strategy, people, partnerships and resources, processes, customer results, people results, society results and key performance results, and has a system of points that are allocated to these criteria based on the results, approach, deployment, assessment and review.

The Intangible Assets Monitor (IAM) [20, 21] is a method for measuring intangible assets and a presentation format which displays a number of relevant indicators for these intangible assets. The choice of indicators depends on the company strategy.

The Skandia Navigator [22] is based on the identification of critical indicators in five perspectives, all of them linked to the value creation process: a financial focus, a customer focus, a process focus, a renewal and development focus, and a human focus. A second-generation model is also available which attempts to consolidate all the different individual indicators into a single index and to correlate the changes in intellectual capital with changes in market value.

The Performance Prism measurement framework was developed by the Centre for Business Performance at the Cranfield School of Management and the Process Excellence Core Capability Group of Andersen Consulting [23, 24]. The Performance Prism has five facets each representing a different perspective on performance.

C. Discussion

The performance management models presented in this section show that:

- Performance management is inherently multidimensional and thus a very complex activity. This may be even more the case for a relatively immature field such as software engineering, the end-product of which is, by definition, intangible.
- Performance management is viewed quite differently from one model to another. In fact, the selected models are quite different in terms of the adopted terminology, the number of perspectives included in the model, the chosen perspectives themselves, and the indicators or measurements within each chosen perspective.
- Organizations cannot adopt performance management models out of the box. They must necessarily be adapted to meet one's own organizational or project goals and objectives.
- Performance management models have been studied and applied quite extensively in management. Performance models used by software engineering managers must adopt terminology and a framework

that is recognized by managers and executives outside their own software engineering organizations.

- Performance management models in software engineering must also, however, support concepts and terminology which are specific to software engineering.
- Performance management models that are specific to software engineering have been studied relatively little.
- Even though many models support multiple levels of goals, objectives and measurements or their equivalents, almost none of the models include a mathematical framework for handling these concurrently in an integrated manner. In addition, almost none of the models include mathematical formulae for consolidating the various performance perspectives and indicators or measurements into a single or unitary index.
- Performance is not one-dimensional, and therefore to understand it, it is essential to view it from multiple, and interlinked, perspectives. Almost none of the models include a sophisticated visualization approach to handle this issue.

III. PROPOSED CONCEPTS FOR A TOOL FOR MULTIDIMENSIONAL PERFORMANCE MODELING IN SOFTWARE ENGINEERING MANAGEMENT

This section describes the high-level characteristics, as shown in Figure 6, of a proposed tool for multidimensional performance modeling for software engineering managers. The proposed tool would:

- adopt the Sink and Tuttle organizational framework of performance;
- build upon the open, generic and geometrical QEST approach to performance modeling;
- enable the selection, by the user, of different visualization techniques to analyze data;
- enable analysis of the impact of future potential scenarios on performance;
- use the International Software Benchmarking Standards Group (ISBSG) database as the initial test bed of data.

Modeling from various viewpoints and at various levels of abstraction is common in software engineering, especially in software design. The first predefined set of viewpoints adopted by the proposed tool would be the performance criteria of Sink and Tuttle: effectiveness, efficiency, quality, productivity, quality of work life, innovation and profitability. This is a more comprehensive framework than BSC for understanding organizational performance. It is easy to understand and adopts terminology that is familiar to all types of managers. Open indicators will also be available to complete the Sink and Tuttle indicators and to adapt the model to a particular situation. "Open" means that an indicator can be defined according to organizational needs.

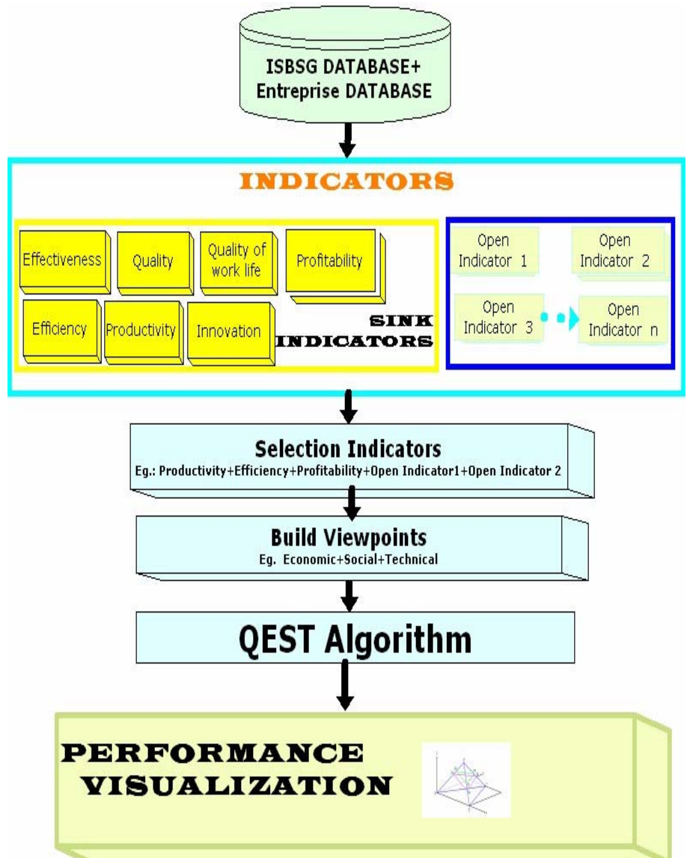

Figure 6 Selection of Indicators for a tool

The QEST model will provide the mathematical and geometrical basis for the tool, because it produces a unitary performance indicator and can handle both quantitative and qualitative measurements. The QEST nD model can handle the seven initial viewpoints proposed by Sink and Tuttle. Additional viewpoints can also be defined according to the objectives of the manager.

To enable the software engineering manager to analyze the multiple dimensions of performance, the tool will offer a set of visualization techniques [25]. Moreover, the tool will allow users to interactively select and combine different visualization and standard data analysis techniques.

The initial test bed for the proposed tool will be the software engineering project data made available by the International Software Benchmarking Standards Group (ISBSG). The ISBSG is a not-for-profit organization whose goal is the development and management of a multiorganizational repository of software project data. This repository is available to organizations, for a nominal fee, and any organization can use it for estimation and benchmarking purposes. The 2005 version of the repository holds data on over 3,000 projects worldwide

IV. SUMMARY

Organizational performance modeling in software engineering management is inherently multidimensional. Although many organizational performance models are proposed in the literature, current performance models in software engineering management do not enable the user to represent many possible viewpoints quantitatively and in a consolidated manner, while at the same time keeping track of the values of the individual dimensions of performance. These models therefore do not meet the analytical requirements of software engineering management when various viewpoints must be taken into account concurrently.

This paper presented a selection of multidimensional models of performance found in software engineering and in management. The paper then described a set of proposed concepts for a tool for multidimensional performance modeling for software engineering managers.

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