LIME: A Three-Dimensional Software Performance Measurement Model for Project Management

Summary:
An open model called **QEST** (**Q**uality factor + **E**conomic, **S**ocial & **T**echnical dimensions) has been developed to handle, simultaneously and concurrently, three-dimensional viewpoints of performance. This model was developed initially to represent multiple views of performance of completed projects. It originally represented a static view of projects. This paper presents an extension to this QEST model, which allows it to be used dynamically throughout a project's life with the flexibility to represent, for example, distinct views of quality depending on the phase of the lifecycle considered. This model is referred to as the **LIME** (**LI**fecycle **ME**asurement) model and can accommodate a lifecycle model where each phase can have distinct relative distributions across the three viewpoints.

Luigi Buglione, Dr., & Alain Abran°, Dr.*, SOFTWARE ENGINEERING MANAGEMENT RESEARCH LABORATORY, Université du Québec à Montréal, C.P. 8888, Succ. Centre-Ville, Montréal, Québec, Canada,
* tel: +39-338.95.46.917, fax: +39-06-233.208.366 , email: luigi.buglione@computer.org
° tel: +1-514-987.3000 (8900), fax: +1-514-987.8477, email: abran.alain@uqam.ca

1. Introduction

The purpose of project management is to ensure that project objectives are met, such as delivering software functionality on time, on budget and within the specified levels of quality, while optimizing the available resources during the full Software LifeCycle (SLC). Over the past few years, the software engineering field has developed an increased awareness of the need to measure both process and product to improve the management of the software development lifecycle. Therefore, quality models such as the earned value and defect distribution analysis models are gaining acceptance in software project management. In the first model, the earned value concept is used for monitoring project expenditures versus expected progress at each project phase, while in the second one, the defects are recorded during each lifecycle phase for defects identification and prevention at earlier phases. There already exist a number of one-dimensional models of performance, which integrate individual measurements into a single performance index. The traditional performance model of an organization is often derived from information within its accounting system, thereby taking into account the economic-financial viewpoint. In the software engineering literature such tangible asset measurement is discussed in performance management frameworks like the Balanced Scorecard (Kaplan & Norton, 1996), the Intangible Asset Monitor (Sveiby, 1997) (Sveiby, 1998) and the Skandia Navigator (Edvinsson & Malone, 1997) (Skandia, 1998). These typical quality models take into account only a single viewpoint of quality, the number of defects, for instance. However, software quality has many other dimensions, such as usability, quality of documentation, associated operational costs, etc. Restricting quality measurement, analysis and management to only a single view of quality throughout an SLC does not meet project management requirements. Current models are too oversimplified to properly reflect the multidimensional nature of performance and of the analytical requirements of management when various "viewpoints" must be taken into account simultaneously. Therefore, to handle simultaneous multidimensional constraints in software projects, management has had to rely mostly on intuitive perception of current project status due to a lack of measurement techniques and models sophisticated enough to do the job. In addition to one-dimensional models, many other issues have been identified by researchers, such as a mix of quantitative and qualitative aspects, as well as integration of product and process analyses (Abran, 1995) (Birk et al., 1998) (McGarry, 1995).

In multidimensional analysis, distinct but related viewpoints of interest can be taken into account simultaneously, each representing a distinct dimension of performance. Such a multidimensional model of software quality has been presented in (Buglione & Abran, 1999a-e) (Buglione & Abran, 2000) (Buglione, 1999), where quality is viewed as the concurrent integration of three different viewpoints in the QEST model[1]:

- **E**conomical: the viewpoint of **management**, who are "*interested in overall quality rather than in a specific quality characteristic* [...] *and the need to balance quality improvement with management criteria*" (Pressman, 1988);
- **S**ocial: the viewpoint of the **user**, for whom software quality is achieved by all the properties required to satisfy, correctly and efficiently, the present and future real needs of whoever buys it and uses it;
- **T**echnical: the viewpoint of the **developer**, for whom software quality is achieved by "*conformity to functional and performance requirements explicitly stated, to development standards explicitly documented and to implied characteristics supposed for every software product developed in a professional way*" (ISO, 1991).

This model therefore allows the performance concept defined, as "*the degree to which a system or a component accomplishes its designated functions within given constraints*" (IEEE, 1990) to be addressed. However, the initial QEST model was originally described as a static model to be implemented at a single project phase.

In a competitive market period such as the current one, where the capability of a company to react on time to customers' requests and to minimize the cost of goods and services offered is a survival condition, monitoring performance levels during all SLC phases becomes a key component in improving the planning and the delivery of goods and services, as well as for the design of improvement programs. For example, the costs of finding and fixing the defects in later phases are much higher that in earlier phases (Kan, 1995), and defects should be identified and removed as early as possible, preferably before the testing phases, in order to improve quality and reduce these costs; Dynamic multidimensional quality models would contribute to ongoing analysis during a project lifecycle for the continuous monitoring of project progress and for making adjustments to forecasts and schedules of subsequent phases of projects. An extension to the QEST model, the **LIME** (**LI**fecycle **ME**asurement) model has been developed to handle, simultaneously and concurrently, three-dimensional viewpoints, for the analysis of measurement results throughout the various phases of software development, considering both process activities and intermediate software product deliverables. This paper presents this dynamic extension to the **QEST** model.

The paper is organized as follows. Section 2 describes the key concepts of the QEST model; section 3 describes an overview of its extension, the LIME model, for use throughout the software lifecycle; and section 4 presents a suggestion for the use of the LIME model in process improvement frameworks.

2. The QEST model

This section presents the model proposed initially to present a multidimensional view of performance, a model that will be extended in the next section to represent project performance throughout the lifecycle phases. The initial model is referred to as the **QEST** (**Q**uality factor + **E**conomic, **S**ocial and **T**echnical dimensions) model. In the QEST model[2], the measurement of performance (**p**) is defined as the *integration* of an instrument-based measurement process (expressed in the model by the component **RP** - *Rough Productivity*) with a perception-based measurement process based on the subjective perception of quality (expressed in the model by the component **QF** - *Quality Factor*). The QEST model

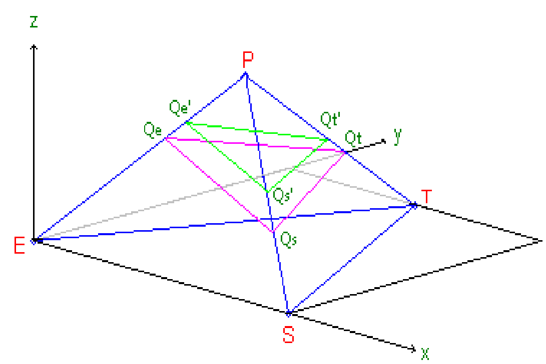

Figure 1 - *QEST model and its hyperplane sections*

[1] The viewpoints listed reflect the perspectives of three possible groups of stakeholders, the same ones who were listed in the ISO/IEC JTC1/WG6 work.

[2] Several publications cover the different aspects of the QEST Model as follows: theoretical aspects (Buglione & Abran, 1999b,c) (Buglione, 1999) , geometrical and statistical foundations (Buglione & Abran, 1999e), implementation of the model (Buglione & Abran, 2000) and the Quality Factor (Buglione & Abran, 1999a).

provides a multidimensional *structured shell*, which can then be filled according to management objectives for any specific project, and is therefore referred to as an *open model*. This topology of performance models makes it possible to handle the multiple and distinct viewpoints already discussed, all of which can exist concurrently in any software project. This section presents the design of this *open model* for the measurement of software project performance. A three-dimensional geometrical representation of a *regular tetrahedron* was selected as the basis for the model, and is illustrated in Figure 1. Furthermore:

- the three dimensions (E, S, T) in the space correspond to the corners of the pyramid's base, and the convergence of the edges to the P vertex, which describes the top performance level;
- when the three sides are of equal length, the solid shape that represents this three-dimensional concept is therefore a pyramid with its triangular base and sides of equal length (*tetrahedron*).

This pyramid-type representation imposes the following constraint: the sides must be equal. This is achieved through giving equal weight to each of the three dimensions chosen – and with sides of length exactly equal to 1 (*regular tetrahedron*); in this way, the dimensions are represented through a normalized value between 0 and 1 for each of them on a ratio scale, for ease of understanding. With this 3D representation, it is possible to determine and represent performance considering distinct geometrical concepts (distance, area and volume). In this representation, the ratio between the volume of the lower part of the truncated tetrahedron and the total volume of the tetrahedron represents the normalized performance level of a project being assessed. The geometrical approach permits representation of the measurement of performance in a simple and visual way. The selection of the regular tetrahedron was also suggested by the idea that the vertex of the 3D shape represents, from a conceptual viewpoint, the convergence of different viewpoint evaluations into a final, single one. Another important factor to take into account is the use of normalized values in order to give management greater value readability to support decision-making.

3. The LIME model

The LIME (**LI**fecycle **ME**asurement) model extends the QEST model concepts to a dynamic context, such that the model can be applicable to each step of any topology of SLC selected[3]. For illustrative purposes only here, the **LIME** model considers a generic 6-phase waterfall SLC structure. The intrinsic SLC dynamicity and sequentiality necessarily imply the adoption of a notation to describe the process and its flows. From the various possible notations found in the technical literature[4], the **ETVX** (Entry-Task-Validation-eXit) notation (Radice & Phillips, 1988) has been selected for use in this paper[5]. Figure 2 expresses the relationship between activities and results, the n^{th} phase of a project along a certain time-flow *t*. In this notation system, the output of the $(n\text{-}1)^{th}$ phase represents the input for the n^{th} one; processing produces the n^{th} output, which will be the input for the $(n+1)^{th}$ phase, and so on. It must be noted that the measurement results ($I_1, ..., I_6, O_1, ..., O_6$) can be added since they have been normalized within the QEST model to facilitate an understanding of them and a representation of them in a 3D space:

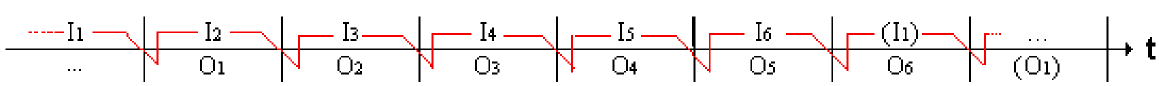

Figure 2 – *Input and output overlapping per phase*

The framework for the LIME model is the following:

---

3 Refer to (Buglione & Abran, 1999d) for SLC definitions and a taxonomy. For the purposes of this paper, the simpler, but also better known, waterfall model is used; the spiral model also uses an SLC with six generic phases (Requirements; Specification; Design; Coding; Testing; Maintenance) and organizations can easily adapt the LIME model according to their own model needs. This flexibility of the proposed performance measurement model is referred to here as an *open multidimensional model of SLC performance*.

4 See http://source.asset.com/stars/loral/process/guide/notation.htm for a review of the main ones.

5 See (McAndrews, 1993) for an ETVX application.

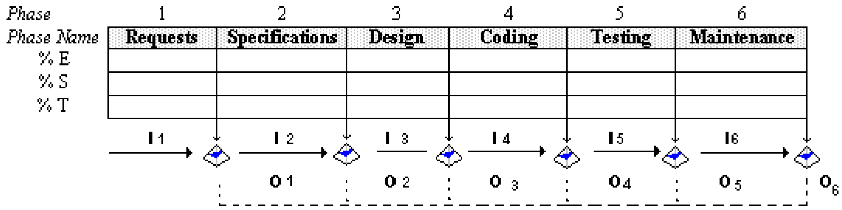

Figure 3 – *The LIME model*

The iterative definition, collection and analysis of multidimensional measures at each lifecycle phase offers, therefore, the feedback required to make adjustments to the project processes in a timely fashion, both for the next phase and for designing future improvements to the process of the preceding phase. This is illustrated in Figure 4 with the four process improvement steps of the **PMAI** (**P**lan – **M**easure – **A**nalyze – **I**mprove) cycle for each of the six phases of the waterfall model considered, based in every phase on a complete QEST assessment. The use of the PMAI cycle into the LIME model requires fewer adjustments than when applied to the QEST model. Basically, Step 1 represents a preliminary step that must be run just only once before starting the measurement program, as similarly for Activity #1 in Step 6 (*Collect project-company data*)[6].

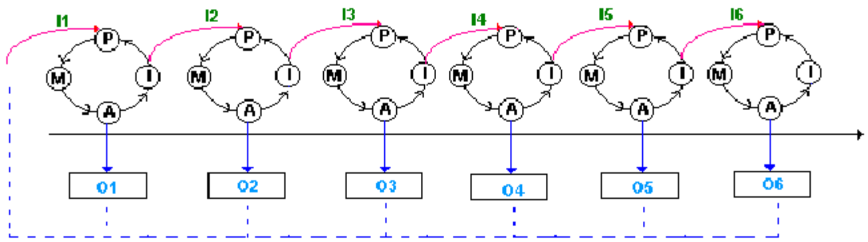

Figure 4 – *LIME model and PMAI Cycle*

The key features added in the LIME model are:

a. Flexibility of distinct relative contributions from the three dimensions (E, S, T) in each phase: Distinct groups of interest bring a contribution to quality during each project phase, and in a distinct relative distribution. For instance, users are not present during the Coding phase and managers might be quite involved in the Testing phase; in parallel, the technical staff is predominantly present during both of these phases. So, in each phase the relative contribution of the three groups must be determined quantitatively in a proper way. This distribution – as illustrated in Figure 5 - must be adjusted at each phase, using one's own project data and historical data from past projects.

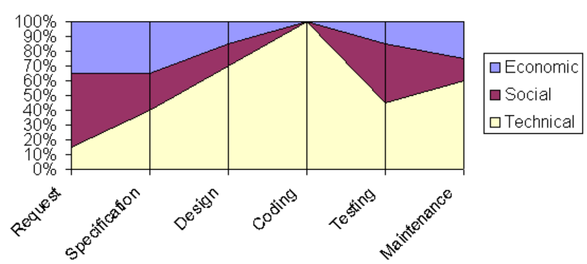

Figure 5 – *Dimensions Distribution*

b. Flexibility of distinct relative contributions of evaluation sources in each phase: Similarly, the characteristics of the relative distributions of instrument-based and subjective evaluations constitute one of the basics of the QEST model. The extension of the QEST model to the whole SLC allows for variable tuples of relative distribution values for each phase.

c. Flexibility in selecting measures and ratios suitable for each SLC phase: The treatment of each single SLC phase makes it possible to select, for each organizational dimension, measures and ratios suitable for each step; an extensive list of candidate measures is provided in (JLC, 1998 - pp. 148-153). The *open* structure of the QEST and LIME models gives the flexibility to use, for any project, any suitable measures as recommended by the organizational measurement group, in cooperation with the representatives for each dimension.

---

[6] For further details about PMAI cycle, steps and activities, refer to (Buglione & Abran, 2000).

4. Usage in process improvement frameworks

This dynamic use of the QEST model makes it possible to benefit from a measurement activity during the various software production phases, considering activities and results from a process viewpoint; this makes it useful for monitoring quality dynamically with respect to forecasts and schedules. In fact, it is possible to think in terms of a representation of activities and results between successive phases, as in the ETVX process definition notation. The dynamic feature of the LIME model enables iterative definition, collection and analysis of multidimensional measures at each lifecycle phase, and therefore offers more timely feedback for making adjustments to project processes prior to project completion. For example, each SLC phase could be viewed as a group of processes, which in turn could be broken down into a series of processes and activities. For example, the SPICE[7] model (ISO/IEC TR-2 15504) (ISO, 1998), summarized in Figure 6, proposes a framework based on three *process groups*, each of those including one or more *process categories* each of which contains multiple *processes*, for a total of 24 processes, which is turn can be broken down into *activities.*

PROCESS GROUP	PROCESS CATEGORY	NO. OF PROCESSES	NO. OF ACTIVITIES
PRIMARY	**CUS** (*Customer/Supplier*)	4	44
	ENG (*Engineering*),	2	53
ORGANIZATIONAL	**MAN** (*Management*)	4	34
	ORG (*Organization*)	6	61
SUPPORTING	**SUP** (*Support*)	8	53

Figure 6 - *SPICE Processes and Activities*

In a SPICE model, the basic elements to be considered in the use of the LIME model can be the single process. In the PLAN phase of the PMAI cycle (Buglione & Abran, 2000), one step addresses the linking of the measures chosen to the corresponding process of the SPI framework chosen, such as SPICE. Then, thresholds should be set for each measure as control limits; a lower value would indicate which process must be verified and controlled. Another aspect is the monitoring of the coverage level of processes, with reference to the SPI framework chosen. An illustration of this is presented in Figure 7 using the five SPICE process categories for a generic *x-th* SLC phase.

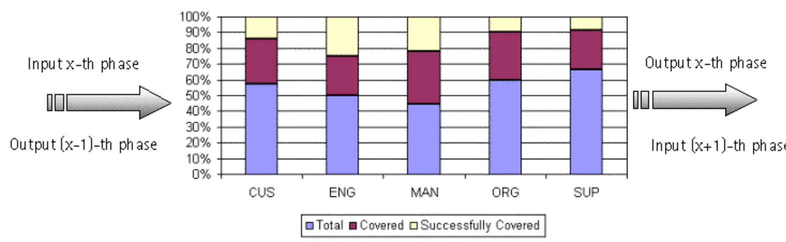

Figure 7 – *Process Coverage in each SLC phase*

Of course there is a cost to collect data on quality and performance at each lifecycle phase. As usual, this represents the cost of better and faster information for improving the decision making process much earlier in a project life cycle, thereby minimizing the risks of not meeting project targets. Indicative effort estimates for each SLC phase have been included in Annex 1[8].

5. Summary

In this paper we first presented the QEST model (**QEST - Q**uality factor + **E**conomical, **S**ocial & **T**echnical dimensions) which makes it possible to move from a one-dimensional representation of quality to a multidimensional representation in order to include the various aspects - technical, economic and social – that exist concurrently in every organization. Then, a dynamic multidimensional model, called **LIME** (**LI**fecycle **ME**asurement), was proposed. The framework of the LIME model was presented and its key concepts illustrated through a generic 6-phase waterfall SLC model, where each output of the $(n-1)^{th}$ phase represents the input for the n^{th} one, and so on, thereby enabling the analysis of the quality of deliverables for current and subsequent processes. This approach makes the analysis of measurement results more comprehensive and

---

[7] SPICE version 3.03 is aligned with ISO/IEC 12207 standard (ISO, 1995).

[8] Annex 1 can be downloaded at: http://www.geocities.com/lbu_measure/qestlime/annex1.pdf

useful by providing a multidimensional representation of performance, with the possibility of analyzing each single dimension and any SLC phase of a project. Such ongoing analysis during a project lifecycle is useful for the continuous monitoring of project progress, including quality, and for making adjustments to forecasts and schedules of subsequent phases of projects.
To minimize data manipulation and analysis at each phase, a software tool prototype is being built to simplify the data collection procedures and to automate the data multi-dimensional representation, as well as data analysis.

References

(Abran, 1995) ABRAN A.: Quality – The Intersection of Product and Process, The 6th IEEE International Software Engineering Standards Symposium, ISESS'95, Montréal, Québec, Canada, August 21-25, 1995, IEEE Computer Society Press.

(Birk et al., 1998) BIRK A., DERKS P., HAMANN D., HIRVENSALO J., OIVO M., RODENBACH E., VAN SOLINGEN R. & TARAMAA J.: Applications of Measurement in Product-Focused Process Improvement: A Comparative Industrial Case Study, ISERN, Technical Report ISERN-98-25, August 1998.

(Buglione, 1999) BUGLIONE L.: Misurare il software. Quantità, qualità, standard e miglioramento di processo nell'Information Technology, Franco Angeli, ISBN 88-464-1729-1, 1999.

(Buglione & Abran, 1999a) BUGLIONE L & ABRAN A.: A Quality Factor for Software, Proceedings of QUALITA99, 3rd International Conference on Quality and Reliability, Paris, France, 1999, March 25-26, pp- 335-344.

(Buglione & Abran,, 1999b) BUGLIONE L. & ABRAN A.: Multidimensional Software Performance Measurement Models: A Tetrahedron-based Design, Rapport de Recherche No, 99/01, Département d'informatique, UQAM, Université du Québec à Montréal, 14 Mai 1999.

(Buglione & Abran,, 1999c) BUGLIONE L. & ABRAN A.: Multidimensional Software Performance Measurement Models: A Tetrahedron-based Design, in "Software Measurement: Current Trends in Research and Practice", R. Dumke/A. Abran (eds.), Deutscher Universitats Verlag GmbH, pp. 93-107, 1999, ISBN 3-8244-6876-X

(Buglione & Abran,, 1999d) BUGLIONE L. & ABRAN A.: LIME: A Three-dimensional Measurement Model for Life Cycle Project Management., Proceedings of the 9th International Workshop on Software Measurement (IWSM99), September 8-10, 1999, Lac Superieur, Québec, Canada, pp. 108-119

(Buglione & Abran,, 1999e) BUGLIONE L. & ABRAN A.: Geometrical and Statistical Foundations of a Three-dimensional Model of Performance, "International Journal of Advances in Engineering Software", Elsevier Publisher, Vol. 30 No. 12, December 1999, pp. 913-919.

(Buglione & Abran,, 2000) BUGLIONE L. & ABRAN A.: Implementation of a Three-Dimensional Software Performance Measurement Model, Technical Report, Université du Québec à Montréal, to be published, 2000.

(Edvinsson & Malone, 1997) EDVINSSON L. & MALONE T.: Intellectual Capital: Realising your Company's time value by finding its hidden brainpower, Harper Collins, NY, 1997, ISBN 0887308414

(IEEE, 1990) IEEE: Standard Glossary of Software Engineering Terminology, IEEE Std 610.12, 1990

(ISO, 1991) ISO/IEC: International Standard 9126: Information Technology – Software product evaluation – Quality characteristics and guidelines for their use, 1991.

(ISO, 1995) ISO/IEC JTC1/SC7/WG7: International Standard 12207 – Information Technology: Software Life Cycle Processes, 22/02/95.

(ISO, 1998) ISO/IEC JTC1/SC7/WG10: Technical Report type-2 15504 - Information Technology: Software Process Assessment, 1998

(JLC, 1998) JOINT LOGISTIC COMMANDER: Practical Software Measurement – A Foundation for Objective Project Management, Version 3.1, Joint Group on Systems Engineering, April 17, 1998.

(Kan, 1995) KAN S.H.: Metrics and Models in Software Quality Engineering, Addison-Wesley, 1995, ISBN 0201633396

(Kaplan & Norton, 1996) KAPLAN R.S. & NORTON D.P.: The Balanced Scorecard: Translating Strategy into Action, Harvard Business School Press, 1996, ISBN 0875846513

(McAndrews, 1993) MC ANDREWS D.R.: Establishing a Software Measuring Process, SEI Technical Report, CMU/SEI-93-TR-16, July 1993.

(McGarry, 1995) MCGARRY F.: Product-Driven Process Improvement, Software Process Newsletter, IEEE Technical Council on Software Engineering, No. 2, Spring 1995, pp. 1-3.

(Pressman, 1988) PRESSMAN R.: Software Engineering: A beginner's guide, McGraw-Hill, 1988, ISBN 0-07-050790-2

(Radice & Phillips, 1988) RADICE, R. A. & PHILLIPS, R.W.: Software Engineering: An Industrial Approach, Prentice-Hall, 1988, ISBN 0-13-823220-2

(Skandia, 1998) SKANDIA GROUP: Skandia UNIC: Universal Networking Intellectual Capital, 1998, URL: http://www.skandia.se/group/fininfo/frame_annual_reports.htm

(Sveiby, 1997) SVEIBY K.E.: The New Organisational Wealth: Managing and Measuring Knowledge-Based Assets, Berrett-Koelher, San Francisco, 1997, ISBN 1-576-75014-0

(Sveiby, 1998) SVEIBY K.E.: The Intangible Asset Monitor, 1998, URL: http://www.sveiby.com.au/IntangAss/CompanyMonitor.html

Return to INDEX

Return to GENERAL PROGRAM