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Framework for quantitative S/W Development Performance Measurement and Analysis in Semiconductor Industry

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반도체 산업에서 정량적인 소프트웨어 개발 능력 측정 및 분석을 위한 프레임워크

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Abstract This paper presents a framework for quantitative software development performance measurement and analysis based on characteristics of software in System on Chip (SoC) industry, one of the semiconductor businesses. In this paper, we propose a measurement model based on not only theoretical model (Performance Pyramid) but also characteristics of SoC embedded software. Quantitative software development performance measurement is not just collecting indicators but analyzing quality, cost, and delivery (QCD) of collected indicators. Externally, it is possible for programmers to develop software meeting customers' needs. Internally, more efficient software development can be possible through the visible productivity increase. Using the proposed framework, the paper quantitatively measures embedded software development performance.

요 약 본 논문은 반도체 사업의 하나인 SoC에서 소프트웨어의 특성을 바탕으로 정량적인 소프트웨어 개발 능력을 측정하고 분석하기 위한 프레임워크를 제시한다. 본 논문에서는 이론적 모델(능력 피라미드) 뿐만아니라 SoC 임베디드 소프트웨어의 특성에 기반을 둔 측정 모델을 제안한다. 정량적인 소프트웨어 개발 능력 측정은 단지 지표를 수집하는 것만이 아니라 수집된 지표의 품질, 비용, 납기(QCD)를 분석하는데, 외부적으로는 프로그래머가 고객의 요구를 만족하는 소프트웨어를 개발할 수 있게 해주고, 내부적으로는 가시적인 생산성의 증가로 좀 더 효율적인 소프트웨어 개발이 가능하게 해준다. 제안된 프레임워크를 사용하여, 논문에서는 정량적으로 임베디드 소프트웨어 개발 능력을 측정한다.

Key Words : S/W Development Performence Measurement, Key Performence Indicators(KPIs), quality/cost/delivery(QCD), System on Chip(SoC), Framework

1. Introduction

Nowadays lots of companies and organizations are making great efforts to measure software development performance. However, it is hard to have domain-specific measurement and analysis models. Even though, the importance of software in the semiconductor business is getting bigger and bigger and the software market in System on Chip(SoC) industry is dramatically growing, there is no specific software development measurement model based on characteristics of SoC embedded software.

If, accordingly, projects performance is measured by a single criterion without regard for characteristics of domains, it is almost impossible to measure the precise performance.

Hence, the paper proposes a performance measurement

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model that considers domain -specific characteristics of software projects and a framework that automatically collects and analyzes its data in the software development process.

In section 2, we review semiconductor business, GQM (Goal-Question-Metrics) process and approach. The framework for quantitative S/W development performance measurement is presented in section 3. In section 4 and 5, we give the ECM(Earned Value Calculation) model and several case studies of ECM model.

2. Basic Study

2.1 Basic concepts of the semiconductor and the appearance of the semiconductor business

Basically semiconductors can be categorized into two types: memory semiconductors that stores information and non-memory semiconductors, also known as System on Chip (SoC), that performs operation and control functions without information storage.

As, in addition, semiconductor is a component, it has various classification systems according to the uses, technologies, integration levels, manufacturing processes, and so on. Also, each country has its own classification [1].

Since SoC implements a system in a small, single semiconductor chip performing several functions that a system requires such as logical computation or data transformation, there are lots of advantages to use it.

However, SoC technology requires not only advanced hardware techniques but also high level software development skills [1]. Converging and integrating those technologies, SoC research and development accompany with an enormous investment [1].

The appearance of the SoC industry like this is now changing growth factors of the semiconductor business. Also, SoC makes an appearance in the market as a new business model [1].

2.2 The trend of the technology development and the prospect of the technical competitiveness in Korea semiconductor business

The core technology development trend of the semiconductor business in Korea is moving from memory to SoC.

Korean semiconductor industry has relatively high technical competitiveness in memory business compared to United States of America and Japan, while the state of the art in non-memory business is remarkably immature like the following Table 1 shows.

[Table 1] The prospect of the technical competitiveness in Korea semiconductor business[1]

	Country having the highest techno-logy level in the industry	Tech-nical level of Korea	Promi-sing tech-nolog-ies	Immature technologies
Memory	100 (Korea)	100 (2005) →100 (2020)	D,P,M RAM Flash, Re RAM.	Indigenous technologies
Non-memory	100 (USA)	85 (2005) →100 (2020)	Media SoC, Comm-unity SoC, Indust-ry SoC, LED.	- Indigenous technologies for design and IP holdings - International standard technologies and intellectual property rights management

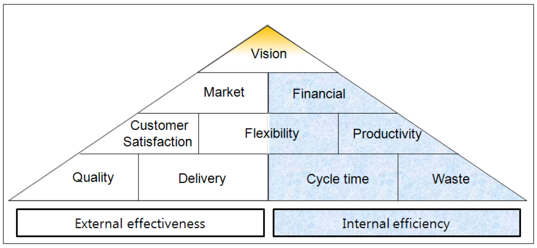
Korean semiconductor industry has not done much in the area of application software, implementation methods, and so on.

2.3 GQM (Goal-Question-Metrics) Process

GQM process is a series of procedures as follows:

- Set an organization's goals through GQM approach.
- Set goals of project in each area.
- Make questions and develop metrics measure accomplishment of the goals using the metrics.

As shown in Fig. 1, GQM process is generally composed of a vision, objectives, and areas belonging to external effectiveness or internal efficiency [2-4].



[Fig. 1] Lynch and Cross's Performance Pyramid

2.4 GQM(Goal-Question-Metrics) Approach

GQM approach involves three steps.

First is a conceptual step. It consists of elements such as object, purpose, viewpoint and focus. In this step, major goals are set. (We selected goals such as quality, delivery, cycle and waste.) Second is an operational step. In this step, questions are derived from the goals that must be answered in order to determine whether the goals are achieved. It asks questions for the way the assessment / achievement of specific goal by each goal. Third is quantitative step in which proper answers are given to the questions.

Through the three steps, metrics system is created. These metrics can be used as a measurement tool which metrics a set of data is associated with every question in order to answer it in a quantitative way [4-7].

3. Framework for quantitative S/W Development Performance Measurement

This section suggests a framework to quantitatively measure organization's project performing capability. Based on the performance pyramid, we made quantitative GQM questionnaires with GQM approach to measure performance of an organization and calculate the earned value.

A quantitative GQM questionnaire is composed of questions to measure the extent to which external effectiveness and internal efficiency of an organization reach the goals. In each area, a project goal is set and a strategy for project process improvement is determined with GQM method and measured.

In addition, accuracy and reliability are highly important factors in data collection. However, responsibility for collecting data is mostly shifted on developers, and as a result it lowers accuracy and reliability of the collected data.

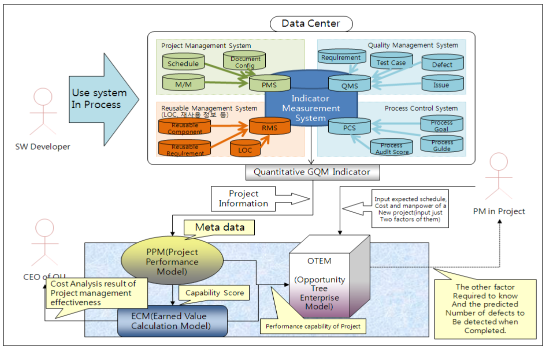
To solve this problem, accordingly, this chapter proposes a framework that can guarantee accuracy and reliability of data collection.

In most cases, project results are delivered from developers to analyzers for the purpose of data collection and measurement after projects are completed.

Therefore, it is necessary for developers to measure data automatically by using proper infrastructure tools during the software development process. It makes possible to measure and analyze real data in progress.

In other words, we can collect data automatically and then guarantee data accuracy and reliability by using various tools such as project management(MS-Project), configuration management(ClearCase), defect management (ClearQuest), requirement manage- ment(Doors), and test management at the software development phase [8].

The following Fig. 2 shows a framework for collecting data.



[Fig. 2] Automation framework for data collection

3.1 GQM Quantitative Indicator from Project Meta Data

This section proposes GQM quantitative indicators made from general meta-data. Procedures for making the indicators involve three steps: setting goals; giving questions; gaining metrics.

First is conceptual step. It consists of elements such as object, purpose, viewpoint and focus. In this step, major goal are set. Second is operational step. In this step, questions are derived from the goals. Third is quantitative step in which proper answers are given to the questions.

Through the three steps, metrics system is made. 20

measurable metrics were made for 8 questions.

The meta-data constituting 8 questions and 20 metrics become elements of the measure method for PPM model which is needed to calculate metrics and also become performance measure elements of PPM model.

3.2 Project Performance Measurement (PPM) Model

This section proposes PPM to calculate project capability in terms of external effectiveness and internal efficiency of an organization.

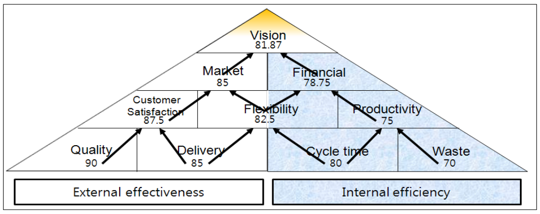
Calculation forms to measure a project performance of an organization in terms of external effectiveness and internal efficiency for 4 goals are shown in [Table 2].

[Table 2] Calculation forms to measure a project capability of an organization in terms of external effectiveness and internal efficiency

External effectiveness	$PPM(QD) = \frac{PPM(Q)+PPM(D)}{2}$
PPM(q): quality effectiveness score	$\frac{\sum Defect\_management\_rate - (100 - [each\_defact\_rate])}{4}$
PPM(d): Schedule effectiveness score	$\frac{\sum (100 - [on\_schedul\_rate\_at\_each\_stage])}{5}$
Internal efficiency	$PPM(QD) = \frac{PPM(Q)+PPM(D)}{2}$
PPM(c): effort efficiency score	$\frac{\sum ((\text{effort\_correspondence\_rate\_at\_each\_stage})}{4}$
PPM(w): resource efficiency score	$\frac{\sum Allfactors - (2 \times (100 - [rework\_rate\_per\_code])}{6}$

By using the calculated PPM(quality and delivery for external effectiveness of an organization and cycle time and waste for internal efficiency), companies can benchmark when comparing their performance with competitors and know how much the organization's external effectiveness is improved.

Scores of quality, delivery, cycle time, and waste in each area are calculated as shown in the [Fig. 3]. The calculated vision value allows an organization to see how closely the project has reached its vision.



[Fig. 3] Performance Score by area calculated through PPM

But with the arithmetically calculated performance of an organization alone, effective process strategies cannot be developed.

Therefore, this paper proposes ECM (Earned Value Calculation) model which can reflect various SoC Development experiences of process improvement and organization's vision.

4. ECM (Earned Value Calculation)

This section proposes ECM model to find an optimal route for improvement. The model integrates project performing capability calculated through PPM and weight of visions of stakeholder obtained through qualitative questionnaire. ECM model is used to determine priority for improvement and performance scores to accomplish improvements in compliance with the organization's vision, which is impossible with simple calculation alone through PPM.

For this, each focus of the performance pyramid selects one of 8 routes for improvement reflected with stakeholders' viewpoint as shown in [Table 3].

[Table 3] Route for improvement

Business unit[Bu]	**Core business process[Cp]**	**Depart -ment groups [Dg]**	**Route for improvement [Ri]**
[M]arket (External effectiveness)	[C]ustomer Satisfaction	[Q]uality	MCQ = [M]+[C]+[Q]score
		[D]elivery	MCD = [M]+[C]+[D]score
	[F]lexibility		MFD = [M]+[F]+[D]score
[F]inancial (Internal efficiency)			FFD = [F]+[F]+[D]score
		[C]ycle time	MFC = [M]+[F]+[C]score
			FFC = [F]+[F]+[C]score
	[P]roductivity		FPC = [F]+[P]+[C]score
		[W]aste	FPW = [F]+[P]+[W]score

5. Case Study and Verification of Reliability of ECM Model

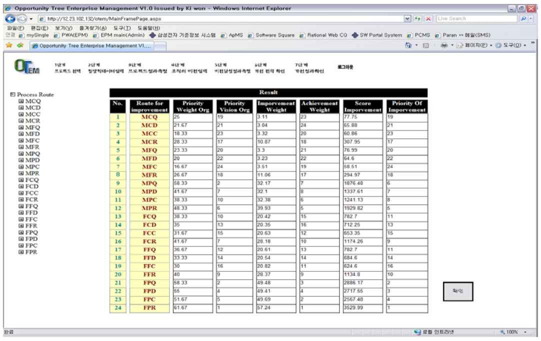
This paper uses project data on 3 projects (hereafter Project A, Project B, and Project C). Table 4 shows specifics on those three projects.

[Table 4] Specifics on Each Organization for Case Study

	Project A	**Project B**	**Project C**
Kind of Task	Develop-ment task	Commerciali-zation task	Develop-ment task
Existence of Mother Task	Exist	Exist	Not exist
Project Cost	About 800 million won (about 700 thousand USD)	About 5000 million won	About 1000 million won
Project Motive	For commission from other organization	For commission from other organization	For internal study of the organization
Project Domain	Mobile	Memory	Multimedia

5.1 Case Study of ECM Model

For case study, this paper uses collected data on the 3 companies by using Excel as an automation tool. Fig. 4 shows calculation results of Project A.



[Fig. 4] ECM Model Results (MCD, MFD)

The verification result of reliability of the 3 companies through case study is as follows. Table 5, Table 6 are summarized results of the case studies.

[Table 5] PPM Case Study Results

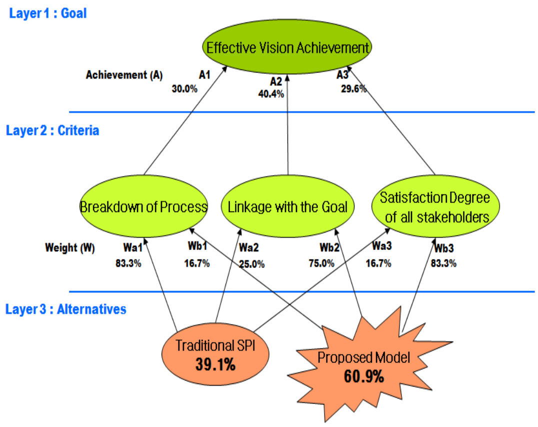
	PPM capability score	**Capability score of each goal**	
Project A performance 71.61	95.08 PPM(QD)	96.48	93.68
		Quality > Delivery	
	48.14 PPM(CW)	46.82	49.47
		Cycle Time < Waste	
Project B performance 69.17	80.16 PPM(QD)	88.97	71.34
		Quality > Delivery	
	58.18 PPM(CW)	69.12	47.23
		Cycle Time > Waste	
Project C performance 79.85	86.66 PPM(QD)	87.42	85.9
		Quality > Delivery	
	73.03 PPM(CW)	59.49	86.57
		Cycle Time < Waste	

[Table 6] Rooted Word List

	Route For improvement (First priority/ second priority)	**Most weighted rooted word**
Project A 60	MCD	Version Management
		Proceeding Management
	MFD	Change Management
		Plan Management
Project B 70.79	MFD	Change Management
		Plan Management
	MCD	Version Management
		Proceeding Management
Project C 75.58	FFC	Standard Setting
		Infrastructure Use
	FPC	Standard Modification
		Data Use

5.2 Verification Using AHP(Analytic Hierarchy Process) Estimation Technique

The fourth step of the AHP Estimation Technique calculates the comprehensive value of the alternatives by integrating the degrees of importance of elements obtained in each level. AHP Estimation Technique [Step 4] − Calculation of Comprehensive Value



[Fig. 5] Calculation of Comprehensive Value result based on AHP Estimation Technique

As seen in Fig. 5, quantitative ECM model got 0.218 higher scores than existing SPI method. Therefore, it proves that the quantitative ECM model is superior to the existing SPI. In addition, the ECM model is given with theoretical reliability with this.

6. Conclusion and hereafter research

Scores of 4 work performance units (Q, D, C, and W) are calculated using PPM. Based on the scores, the priority of 8 routes for improvement is output from ECM. When inputting this result to ECM, root words of issues for process improvement are shown based on SoC S/W Development results.

From the results of this paper, following two advantages can be obtained.

First, quantitative project performing capability of an organization can be measured using PPM model before it works to improve processes in earnest.

Second, the optimal strategy for process improvement can be developed by deriving areas for improvement with ECM model based on current performance capability of the organization, priority of improvement strategies which reflect stakeholder's vision with ECM and SoC S/W Development data. In this case, 4 performance units (quality, delivery, cycle time, and waste) need practical reliability verification through experiential case study by web-based tool using each typical performance.

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