A Measurement-based Approach to Software Development Process Tailoring in R&D Organization

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Abstract— **In case of R&D (Research and Development) organization, the problems of SPI (Software Process Improvement) are focused on how to tailor the process properly because researchers always ask to take the least time and the most benefits for implementing established processes. Process tailoring strategy is a key to attract the researchers for applying the processes. It is a challenge for EPG (Engineering Process Group) to find out the best solution for the organization. EPG has to prove if the software development processes are suitable for the research. Measurable CSF (Critical Success Factors) and how to tailor appropriately influences the quality of the process.**

Keywords-Process Tailoring Strategy; Software Process Improvement; Engineering Process Group; Critical Success Factor

I. INTRODUCTION

Referring to Process Maturity Profile 2012 by SEI [1], many organizations have been struck at CMMI (Capability Maturity Model Integration) Maturity Level 3 because of missing quantitative project data; this is valid especially for government organizations, which tend to apply international standards for AEC (ASEAN Economic Community) opportunity. MA (Measurement and Analysis) is an important process area from all the 22 process areas which CMMI has specified and it affects to upgrade SPI in the organization. The problem is that there is no experience in this process. NECTEC tries to do research about it and expects to make the SMEs to understand better in MA.

Each software development project can have different SDLCs (Software Development Lifecycles) depending on its constraints that can be size, cost, effort, time, customer requirement, business/project goal, capability, culture, etc. There are various SDLCs including Waterfall Model, V-shaped SDLC, Structured Evolutionary Prototyping Model, RAD (Rapid Application Model), Incremental SDLC, Spiral SDLC, Agile SDLC, etc. Each SDLC has strengths and weaknesses which collect from past implementation [4]. But, each organization can adapt them to align with its optimizing processes like NECTEC where tailors Agile SDLC to be own SDLC called "Adaptive SDLC". Currently, agile methodology [18] is capturing more, especially the extreme method and a survey indicates percentage of companies which get better responses in main aspects such as 93% productivity, 88% quality, 49% cost and 83% business satisfaction [2]. Positive and Negative features from implementing agile methodology are identified in Figure 1.

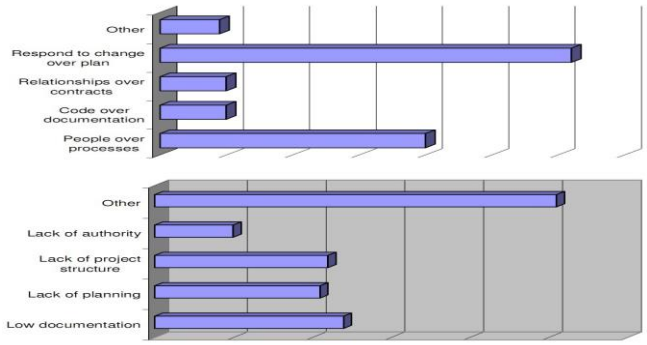

Figure 1. Positive and Negative features from implementing Agile [2]

Some perspectives for the organizational requirement of a metrics program have been classified [10]. Three main factors, which affect the SPI program, include senior management commitment, clear and relevant SPI goals, and staff involvement, as shown Figure 2.

Factor	Goldenson	El Emam	Stelzer
Senior management commitment	Yes	Yes	Yes
Clear & relevant SPI goals	Yes	Yes	Yes
Clear, compensated assignment of responsibility for SPI	Yes	Yes	
Staff involvement	Yes	Yes	Yes
SPI people highly/well respected	Yes	Yes	
Staff time and resource	Yes	Yes	
Creating process action teams		Yes	
Change agents and opinion leaders			Yes
Encouraging communication and collaboration			Yes
Managing the SPI project			Yes
Providing enhanced understanding			Yes
Stabilising changed processes			Yes
Tailoring improvement initiatives			Yes
Unfreezing the organization			Yes

Notes: An 'empty' cell indicates that the factor was not studied by the respective researchers.

Figure 2. Factor affecting to SPI program [11]

Seven advantages of Measurement are identified in Rational Edge article. They include 1) Improve visibility, 2) Communicate effectively, 3) Identify and correct problems early, 4) Make key trade-off, 5) Track specific

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project objectives, 6) Manage risks, and 7) Defend and justify decisions and plan future projects. However, it is hard to establish measures because of no having certain set for all organizations. It depends on their strategy, technology, and the route of competition.

First an overview of measurement-based methodology is provided. Then the paper presents a result of implementing measurement in R&D organization and how to work with MA process. The CSF for the MA implementation is identified. Finally, an effort to find out the better measure for R&D work is proposed.

II. METHODOLOGY

A. Measurement and Analysis Process based on CMMI

Measurement and Analysis (MA) process area is grouped in support category. Its objective is to develop and maintain measurement capability for supporting management information needs. There are 2 specific goals; each goal consists of 4 practices to fulfill the goal. The goals are to align measurement and analysis activities and to provide measurement results. CMMI just guide what to do so each organization has to find out how to do the best. Each organization can have different MA process depending on its goal. The process can be changed periodically because the organization can change its goal. Figure 3 shows the relationship between MA process and other processes.

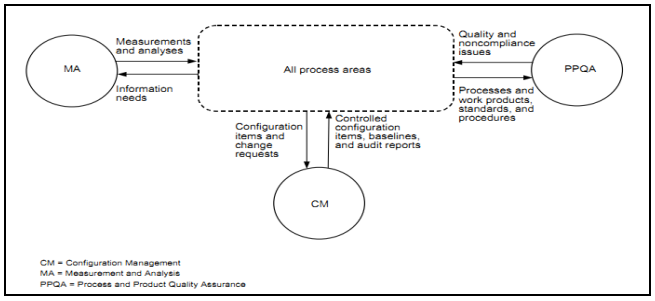

Figure 3. The relationship between MA process and others [14]

B. MA Process Evaluation Approach

The measurement management in organization has several methodologies. The Software Engineering Institute (SEI) published an interesting method called "Measurement and Analysis Infrastructure Diagnostic Method (MAID)". MAID guides the organizations to evaluate key characteristics of their measurement programs [15]. This method is based on criterion. A set of criteria for evaluating each MA process has been introduced in [15]. The MAID method has four phases comprising (1) Measurement Planning, (2) Data Collection and Storage, (3) Data Analysis, and (4) Measurement Reporting. The criteria are implemented by evaluation team in the 2nd and 3rd phase. We tried to apply MAID method to appraise the CMMI-based MA process. Some activities have been selected to be implemented, such as Review MA documents, Conduct interviews and examinations, etc. However, the criteria cover various issues including data analysis, reporting, process documentation, etc. Another interesting approach is called "Standard CMMI Appraisal Method for Process Improvement (SCAMPI)", which supports evaluation of CMMI-based process in term of opportunity for improvement (OFI). There are A, B and C types; SCAMPI A is the official appraisal and others will reduce strictness, respectively. Figure 4 presents an appraisal direction [16].

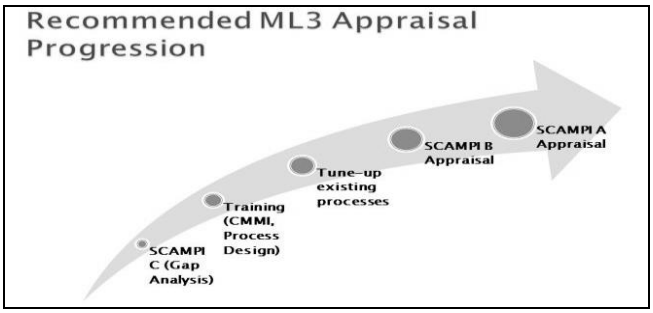

Figure. 4. An example of appraisal method [17]

C. Goal-Question-Metric Paradigm (GQM)

Goal-Question-Metric Paradigm is invented Basili [19] from the University of Maryland College Park and Software Engineering Laboratory at the NASA Goddard Space Flight Center. This approach is based on the idea of goal-oriented measurement. In Figure 8, we apply GQM approach to analyze the measures. We started with analyzing the organizational goals, which came from the executive policy and found out related measures leading to achieve those goals via a set of questions. GQM approach can divided into three levels, as shown in the Figure 5:

- Conceptual Level (Goal): We set up Business Goals that is the goal in the measurement goals.
- Operational Level (Question): We define a set of questions to achieve the goal.
- Quantitative Level (Metric): We formulate the measure to answer the question in Operational Level.

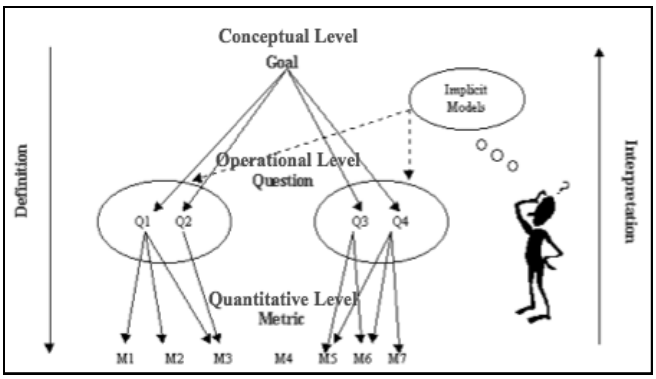

Figure 5. GQM Levels [13]

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III. MEASUREMENT IMPLEMENTATION

A. A Set of Measures for R&D Organization

Primary quality attributes, which impact achievement of the SPI program, are summarized in 5 categories involving performance, stability, compliance, capability, and improvement [7]. Organizational Metrics are aligned with these categories to specify their values. For Project Level, there are different quality attributes categories and supporting metrics. An example of metrics in each category is shown in Table I.

TABLE I. AN EXAMPLE OF METRICS IN QUALITY CATEGORIES [7]

Level	Quality Category	Example of Supporting Metrics
Organization	Performance	Completeness of requirement, Resource utilization versus the plan
	Stability	Effectiveness of Scope, schedule, and cost-tracking processes
	Compliance	Product conformance with requirement, # workarounds required
	Capability	Use of knowledge, skills, and competency profiles
	Improvement	Involvement of individual team members initiatives, Effect of technology in terms of performance improvement
Project	Resource	Cost/budget, Resource Utilization
	Progress	Development progress, Incremental capabilities performance
	Technical	Requirement stability, Design stability, Error margins
	Quality	Defects, Rework, Defect removal rate
	Productivity	Cost performance index, Trends in cost, schedule, efficiency
	Completion Activity	Quality gate task status, Quality gate passed
	Change	Percent change to product baseline per period
	Staff	Percent voluntary staff turnover, Percent overtime
	Risk	Risk impact and reduction, Risk Liability, Anonymous warning

The appropriate measures depend on the organization's strategy, technology, and economic situation [7]. From a survey, top 10 project measures consist of ROI (Return on Investment), Productivity, Cost of Quality, Cost of Performance, Schedule Performance, Customer Satisfaction, Cycle Time, Requirements Performance, Employee Satisfaction and Alignment to Strategic Business Goals [7]. Figure 6 and Table II present some characteristics of R&D works leading to different measures.

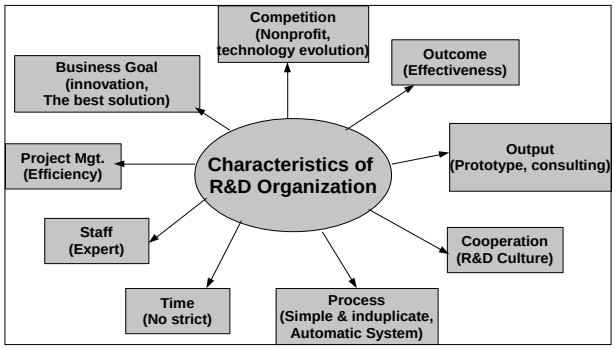

Figure 6.Characteristics of R&D Organization

TABLE II. MEASURES/METRICS SUPPORTING R&D WORKS [7]

Category	Characteristic	Measures/Metrics
Business Goal	Research an innovation	- Improvement Trends/ Pattern - Operational Trends/ Patterns - Alignment to Strategic Business Goals
	find out the best solution	Customer Satisfaction, # problems reduced
Competition	Nonprofit	% research linked to business unit or corporate strategic planning, R&D as a % sales
	Compete with technology evolution	#ideas, #inventions submitted, #patents challenged
Process	Simple and induplicate	Customer Satisfaction
	Supporting Automatic System	% process operated automatically
Staff	expert	% R&D staff with related experience
Time	No strict in time	R&D time variance vs. budget
Outcome	effectiveness	Return On Investment, Work satisfaction, etc.
Output	Lab prototype	Productivity
	Consulting SMEs to upgrade product	Customer Satisfaction, market share
Cooperation	R&D Culture depends on behavior of researcher	Employee Satisfaction
Project Management	Efficiency, Different between planned and actual values	Cost Performance, Schedule Performance

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It is impossible to record all data to respond the related measurement. Thus, the organization should consider the measures from the needs of the executive. How to get data supporting all measures for R&D works has many channels such as GQM, MAID, CMMI, Lesson learned, etc.

Figure 7 presents three types of indicators including success indicators, progress indicators, and analysis indicators [11]. EPG can apply this idea to find out the measures.

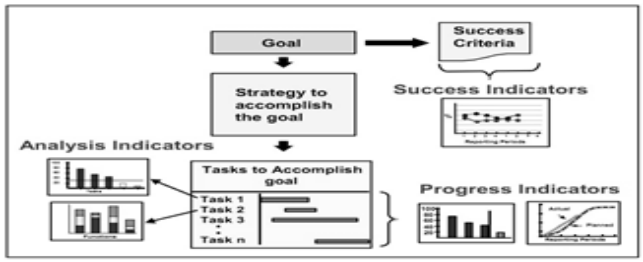

Figure 7. Types of indicators [11]

B. Implementation in R&D Unit

Generally, many organizations including NECTEC start to follow Specific Goals and Practices of Measurement Process Area. NECTEC's EPG established a lot of data for achieving measurement goals but finally users could not record all established inputs because they needed a lot of effort (to understand, to record, to attend, etc.). Moreover, the recorded data was not correct because they usually recorded after related activities had occurred although there were templates to support them completely. Finally, the process improvement program could not achieve measurement activities.

Figure 8 presents mapping the organizational needs to related MA processes and established analysis methods. Table III shows the lesson learned from NECTEC's CMMI implementation (2010-2011) including its strengths and weaknesses. Each role in a project has to record data for supporting the measurement process. There are 10 different templates for project manager to input the data which depends on applied processes. Figure 9 shows an example of MA templates and Table IV proposes the new information needs and how to obtain the best measures for NECTEC or R&D organization comparing strategy from CMMI and GQM.

Subject	Description
Information Need	Quality of the Products.
Measurment Objective	All Requiremnet is recorded.
Information Need for PA	The number requirement recorded for the PA.
Measurement ID	SGL_MA_RR01
Measure	The number requirement recorded from the Customers or the Stakeholders.
Objective	The User Requirement Document (URD) is reviewed.
Releted Processes	PGL_RR_RD01
Type of Measure	BASE
Store Procedures	SA records the number requirement from the template(TP_RR_URD)
Unit of Measure	Record
Tools	Openoffice Calc Version 3.0
Configuration Management	Calc File in MA_RR Sheet (SGL_MA_RR01)
Analysis Methods	1. Count the number requirement of each project. 2. Count the number record in the URD. 3. Compare the number from step 1 and step 2 if the equal.

Figure 8. An example of MA Analysis

TABLE III. LESSON LEARNED FROM IMPLEMENTATING MEASUREMENT PROCESS OF NECTEC (2010-2011)

Needs	#Way to record the Measure by each role	Lesson learned		Suggestion
		Strengths	Weaknesses	
Progress of the project	PM: 10 CM: 1 SA: 4 Dev: 3 Rev: 3 Tester: 1	- all PAs covering measures - Having data to respond all related measures - Recorded by related roles	-no automatic record -spend time to record -often forget to record -a lot of data to record -no use all data -no understand clearly	1. no MA experience 2. no need to record all data initially 3. too difficult to record 4. duplicate record 5. no align with real activities 6. no need to record some measures (get ROI from responsible unit) 7. join with QA or PM to support MA records
Quality of the project	QA: 1 Cus: 1			
ROI of the project	PM: 1			
Others	EPG: 3			

Remarks:
-1st deployment
>>fail (no complete data, no right data, no record immediately, etc.)
-2nd deployment
>>almost fail (some measures are selected to respond some needs but not be satisfied by the stakeholder)

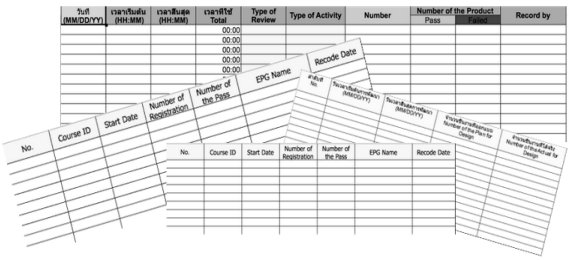

Figure 9. An example of MA templates

C. Lesson Learned from MA Implementation in R&D Unit

The lesson learned from the past implementations makes us understand more about the importance of MA process. Many problems occurred in the MA implementation period as shown in Figure 10. The problems and their solutions are summarized for the next implementation in Table IV.

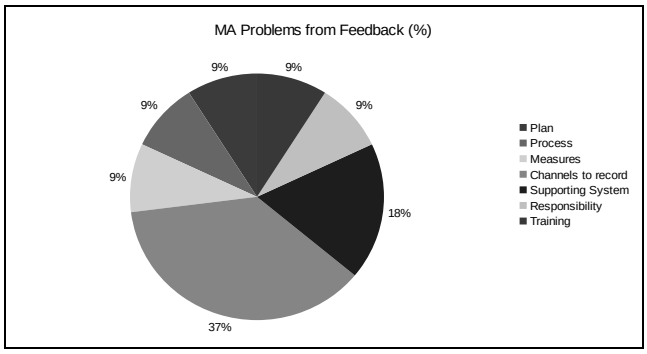

Figure10. MA Problems in SPI Implementation Period (%) [5]

D. Tailoring the Process

There are two levels for tailoring software development process. Firstly, it focuses on organizational process which NECTEC's EPG tries to optimize Software Development Lifecycle (SDLC) models from brainstorming of stakeholders. There are other related processes, such as training process, improvement process, etc. They have to be consistent with organizational policies and goals. Another level is to tailor processes and products in each project. How can one know that each tailoring can respond the information needs completely? A product tailoring template should be established for stakeholder who requests to do other products instead. What is the best criterion for tailoring the process and the product responding to organizational goals? Currently, EPG has to examine each tailoring in each project. If you want to focus on quality of process improvement works, you also have to realize appropriate conditions for tailoring the product. However, alternatives should be considered.

IV. OPTIMIZING MEASURES FOR R&D ORGANIZATION

A. Measures in R&D Organization

This paper presents NECTEC to be representative of R&D organization. We start from current business goals as follows. The measures which come from GQM and survey result are identified as follows:

- Tracking of the project: Milestone completion, Resource utilization, Risk impact and reduction, Project Completions per year, Number of active/on – hold/closed projects, periodically.
- Quality of the project: Product defects, Defects by activity, Deviation from standard.
- Error/fault/failure rates, Product failures, Customer complaints.
- Return on Investment (ROI): Investment in R&D/Project Cost, Evaluated benefits from applying related products periodically, Comparison between cost and evaluated benefits, Customer satisfaction/ dissatisfaction, Customer Retention.
- Engineering Excellence: Depth width and knowledge, Skills and productivity, Building character to perform within moral and ethical framework.

TABLE IV. MA PROBLEMS AND SOLUTIONS

#	MA Aspect	MA Problem	% Feedback (project and appraisal team)	Proposed MA Solution
1	Plan	Don't know why to do MA process	9%	-Clear MA plan and inform to stakeholder
2	Process	Incorrect Steps to record MA leading wrong data (some records)	9%	-clear understanding of the advantage from MA data. -executive supporting policy
3	Measure	Too much for responding the organization 's needs	9%	-Apply GQM methodology to identify the measures (traceability) -Start small and showcase a success
4	Channels to record	Too hard to record	37%	-Access rapidly and easily -Simple Templates and not many templates.
5	Supporting System	No application to support MA process	18%	-Retrieve data from operation automatically
6	Responsibility	No assign the person to track,collect, analyze, summarize, and report all MA records	9%	-Assign a person to track and collect all MA records periodically
7	Training	Forget step to record MA.	9%	-clear understanding of the type and purpose of each indicator -simple guideline to remind MA process/step

NECTEC is implementing these measures for organizational level. The MA result has to respond the executive's information needs or policies. However,

measures in the project level can use some measures from the organizational level and add some measures which impacts to achieve the project goals such as measures proposed to the 1st-2nd business goals. Besides the tailoring the process also has to support the established measures especially in project aspect. Figure 11 shows an example of duplicated measures in different aspects [6].

Individual	Project Team	Organization
Defect rates (by individual)	Defect rates (team)	Defect rates (by project)
Defect rates (by module)	Module size	Size (by product)
Defect rates (under development)	Estimated module size	Effort (by project)
Number of compiles	Number of re-inspections	Calendar times
	Defects per module (prerelease)	Defects per module (post release)
		Effort per defect (average)

Figure 11. An example of duplicated measures in different aspects

B. Tailoring Criteria for R&D Organization

Another important activity which needs measures properly for implementing the project is SW development Process Tailoring. Five main causes enforce EPG to tailor the process including resource, communication, requirement management, political and technical [8]. The process includes all related documentation such as SDLC, template, guideline, etc. Concerning the lesson learned, EPG should tailor the SDLC covering all types of the R&D projects. Currently, NECTEC has tailored the SDLC into 3 types involving waterfall, rapid prototyping, and adaptive models. Each model has different documents that authorized person can request to tailor the documents with his/her reasons. EPG will consider the requests in 2 aspects, which cover related standard goals and established measures.

Another challenge issue needed is to find criteria for choosing the appropriate process (global process model and methods and tools supporting those models), evaluating its suitability and improving it continuously [9]. Referring to the characteristics of R&D works, the measures should be established to evaluate its consistency with the information needs. There are two tailoring level including organization and project levels. The tailoring approach is one of the improvement methodologies. Purpose of tailoring the process in a project is data collection to indicate all candidates of process and work product in R&D work. Error, fault and failure analysis are selected to respond the tailoring purpose. Furthermore, measures which should be also realized for tailoring the process effectively include coverage attribute following the standard process and established measures. EPG has to consider quality in coverage for tailoring both process and work products. The criteria supporting EPG to validate the tailored process is proposed as follows:

- Measures, which respond the organization/project goals from tailoring processes, are still recorded.
- Measures, which respond the organization/project goals from tailoring products are still recorded.
- Tailoring Processes still respond to organization/project goals comparing with default processes.
- Tailoring Products still respond to organization/project goals comparing with default products.
- The process (including related products) still responds to established requirements.

V. CONCLUSION AND FUTURE WORK

This paper presented how to implement MA process in R&D organization and proposes an idea to improve it including measure analysis and tailoring conditions. To apply international frameworks can make officers work professionally. The R&D organization has specific business goal which impacts to establish the measures for indicating quantified improvement level. Tailoring the process is a measure which supports flexible process. How to tailor the process effectively needs to be analyzed systematically.

A set of measures has to adjust in parallel with changed business goals. Moreover, supporting data should be recorded automatically and should not be operated repeatedly by project team. It is a challenge for the next research to refine better processes and measures by analyzing actual result continuously and make them more generic and systematic for distributing their advantages to others.

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