Transforming an Organisational Outcomes to Software Measurement Programs

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ABSTRACT
This paper presents a framework for transforming organizational outcomes into their related software measurement programs. The benefit of this framework is that it can continually measure how well operations or projects lead to the outcomes. The transformation framework has four parts: setting up the program, running the measurement program, analyzing the information products and using the result. The output of this framework is a measurement plan that can produce information products to support both software and organizational measurements. The framework is applied to 3 projects out of 5 projects conducted at SwE Laboratory, Walailak University, Thailand. The results are shown that the projects that use this framework are more consistent with the outcomes. The average time requires to re-run measurements are 5.33 days decreased. In term of user satisfaction, about 73% of the laboratory members are satisfied with the framework where the rests are neutral.

General Terms
Software Life-Cycle Management, Software Measurement, Outcome-Oriented Concept.

Keywords
Organizational outcomes, Software measurement program, Software engineering, OPI, Transformation.

1. INTRODUCTION
Software measurement [1] [2] is a software engineering principle that allows software developers to check the consistency between the developed software and its requirement. In addition to assess software quality, software measurement can be used to understand, control, improve, and predict the software development products, processes and resources. Software measurement environment requires both software development and business management parts. For example, in order to evaluate performance of business operation, a software organization needs to use information product of software measurement report such as software quality, employee's productivity, sales rate, user satisfaction and etc. as the input. Unfortunately, the complete information product may not always be available from the software measurement programs. As a result, if business evaluators may not be able to rely on only the output from such programs. In the extreme case, there may not be information products available for evaluate business operation. For this reason, the organization's outcomes may not be evaluated by using only software measurement programs. One solution to this problem is to transform organization outcomes and their indicators to each related measurement program. This paper presents a novel approach in the form of framework based on such transformation. The proposed framework follows measurement paradigm in both business and software levels. Outcome measurement based on the knowledge of the key steps as described in [3] is applied at the business level. At the software level, the framework follows the ISO/IEC standard 15939 [4] that defined processes for setting and performing the measurement program.

There are five sections in this paper. The first section is this introduction. The second is the related works in the fields of software engineering and outcome-oriented management. Descriptions of transformation framework can be found in Section 3. Section 4 is about the method evaluation and the experiment results. The summary and conclusions are in Section 5.

2. RELATED WORKS
2.1 Trends of Software Measurement
Current trend in software measurement area is to manage and measure the end-results of the organization.The example is the Measurement and Analysis (MA) Process Area in the Capability Maturity Model Integration (CMMI) stated in [5].In addition, there are many measurementstechniques that can be found in size metrics as stated in [6] [7] [8], complexity cohesion, and coupling metrics described in [9] [10],and others are usually align to product entitythat is a normal cases in a traditional software measurement programs [11].

Based on the ISO/IEC 15939 standard [4], the area of software measurement engineering [12] consists of both the management process and measurement sub-areas. Management process refers to the activities that are used to ensure that the software development process is consistent with the organization's policies, objectives, and standards. The measurement process consists of four subprocesses: Planning of the Measurement, Performance of the Measurement, Establishment and Sustenance of Measurement Commitment and Evaluation of Measurement. Three main methods that are popularly used in measurement process are Goals-Question-Metric (GQM) [13], (GQ(I)M) [14] and Practical Software Measurement (PSM) [15] supported in the following level of analysis model (see Figure 1). On the other hand, the SWEBOK suggested BSC [16][17] should be applied to satisfy the "information need" level. OPI [7] is a new method that might fill the gap between BSC and software measurement. A principle of this method aims to define a set

of desired outcomes (O), related perspectives (P) and indicators (I) of measurement.

2.2 Outcome oriented concept

Outcomes [18] [19] encourage an individual to focus on the end state of the result of business objectives. (e.g., increasing productivity, improving quality,decreasing defect rates etc.). Many papers increasingly apply an outcome-oriented approach in many areas, such as academia [20], business and government strategy planning [3], science and technology [21], etc. An outcome-oriented approach is an especially important choice in development and management information technology. For example, OTFACT is a software-based data collection system for measuring assertive technology outcomes [22]. Generally, outcomes can be divided into sets of periods, immediate, intermediate and ultimate outcome Doran, G. T. [23] presented the S.M.A.R.T Objective acronym to define a good objective. This stands for Specific, Measurable, Achievable, Reliable, and Timeframe. This paper focuses on the measurement activities and in outcomes management. Outcome measurement [3] is used to determine and evaluate the results of a process, plan, or program with the intended results. Outcome measurement is divided into two sectors[3]: the private public. In the private sector, outcomes typically mean financial outcomes. One broadly used management tool in this area is a balance scorecard (BSC)[17]. Robert Kaplan and David Norton developed BSC in 1992. This is a method to help resolve a lack of balancing in strategic management. BSC has four main perspectives: finances, customers, internal business processes, and learning and growth. In the public sector, outcomes represent the mandate that citizens entrust to government. Other methods are the key step of outcome measurement [3]. Urban institute developed this method in 2003. This method purposes are to help the non-profit organization to evaluate their operations.

The brief comparison summary of the BSC, key step, and OPI can be described as follows.

BSC was not created for the software measurement. As a result, some elements of BSC do not fit in with measuring software, for instance, perspective elements, scale, and unit of indicator elements. Key step method has thirteen steps like the iso/iec 15939, but these steps are more isolate. OPI can link between designing and developing measures and organizational outcomes but it does not define activities to transform information products among level of measurement.

3. THETRANSFORMATION FRAMEWORK

The framework covers the necessary steps for organizations that wish to transform outcomes into their related software measurement program.,It includes the guidance on establishing and sustaining a software measurement plan and the use of information products. In order to explain the framework, the SwELaboratory at Walailak University, Thailandwill be used as the case study. The outcomes of the organization are presented in the strategic plan shownin Table 1. Each outcome determines strategies, proper indicators, and expected value.

Table 1. Strategic plan of SwE laboratory

Outcome	Strategy	Indicators	2009	2010	2011	2012	2013
Achieve profitability from development software, research, and training.	Create a mechanism for operation	Advertisingseminars and training	1st	2nd	4 th	5 th	>=5 th
		Software innovation					
	Increase income and develop innovations		5	7	7	10	10
		Number of maintenance contacts	-	-	1	1	>=2
	Retain existing customers						
			10%	10%	10%	10%	10%
Provide skills and experiences to all students	Staff has expertise in software development and succeed in their careers	% of staff who have a job in 6 month	-	-	90%	100%	100%
	Staff increase software development skills						
		% increase in experience	20%	30%	50%	80%	80%
		% increase in product quality	0%	20%	40%	80%	80%
		% increasein ability to run multiple processes	0%	10%	20%	30%	70%
Establishment of a standard in software development process	CMMI	Success in CMMI level	-	1	2	>=2	>=3
		To have the best practice in software process	-	1	>=1	>=2	>=2

The framework has four sections; Setting up the program, Running the measurement program, Analysing the information products, and Using the Results. These sections are presentedbelow.

3.1 Setting up the Program

This section defines the scope, responsibility, and schedule of the measurement program. The consideration is of a linkage between two kinds of measurement processes, the outcome and the software.

Step 1: Transform Outcomes and Define the Scope of the Program. In this step, a program manager constitutes the program scope by answering the question "what things are to be measured?", and "what is outcomes of that things?". In software measurement program, measurement teams can define outcomes of measurement from the end-results of each project . In addition, measurement team should explore how many organizational outcomes are associate with these program outcomes. The results from this step are program outcomes and related organizational outcomes.

Step 2: Determination of Responsibility. The next step is to establish a measurement team. Team members work out the details of the measurement process and oversee its initial implementation. Team members should have two groups, core

members and client members. The core members will have the responsibility to implement the software measurement program, such as measurement planner, measurement analyst, measurement librarian, etc. Client members will support the data sources, coordinate the measurement procedure between the project and other parts of the organization, and use the information products to manage the organizational outcomes.

Step 3: Establish a Program Schedule. This step is to define a schedule for running all of the activities of the program.Figure 1 shows the program schedule of agoat/sheep farm project.

From Figure1, the schedule includes activities related to measurement process, role and responsibility. An important point concerning a program schedule is that the workers must think about consistency between a software project and a schedule of outcome measurement. For example, there are three period reports, immediate, intermediate and ultimate. For each period, the reports will be produced according to the information needs of the project and the organization.

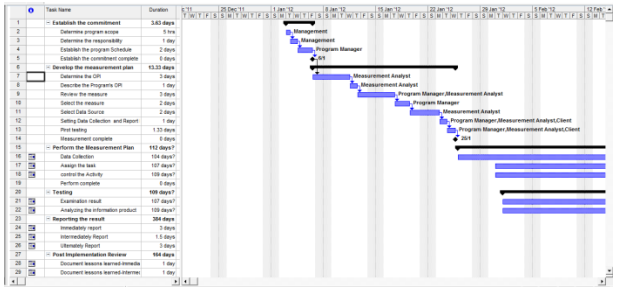

Fig1. Program schedule of the Goat/Sheep Farm Project.

3.2 Running the Measurement Program

This section includes six steps: Program description, Select measure, Data collection, Measure and Reporting schedule, Planning the software measurement process, and Pilot testing through performing the measurement plan.

Step 4: Program description. This steps applies the OPI for transforming and describing outcomes and its information. The principle of this approach aims to define a set of desired outcomes (O), related perspectives (P) and indicators (I) of measurement. In this step, a measurement manager or an analyst can continue to apply the following phases:

Phase 1: Outcome Setting. This is a phase for specifying the required outcomes of the interested entities, often split between interested project and organizational outcomes. In order to describe the program, the measurement team starts bylisting intended majoroutcomes from the interested entity, then subdivides the outcomes to minor outcomes. The next task is the outcomes selection. The measurement team needs to deploy experience and good decision-making tools to prevent the elimination of necessary outcomes.After that, the measurement team should explore the organization level to map the organizational outcomes. One consideration is the periods of outcomes. The measurement team must also bear this aspect in mind when considering the measurement plan.

Figure 2 presents an outcome hierarchy of the goat/sheep farm project. The project, program outcomes and organisational outcomes will link to the indicators.

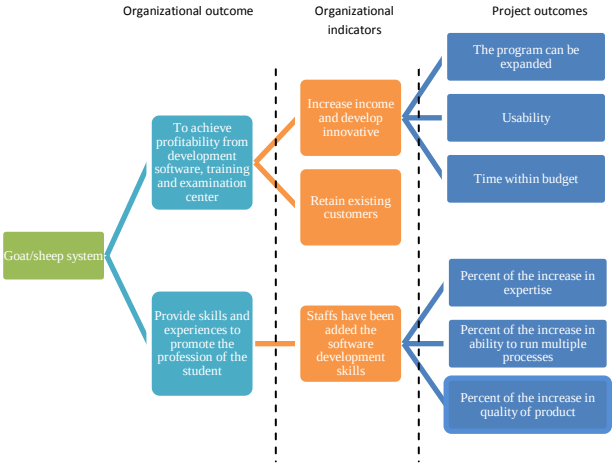

Fig 2: Goat/Sheep farm: An outcome hierarchy

Phase 2: Perspective Defining. This phase starts with considering and searching for perspectives from circumstances related to the outcomes. This paper supports the categorization of perspectives according to perspective determination based on the framework invented by Kaplan and Norton. The other perspectives of the end user, developer, structure, security, or maintenance may be included. In

addition, determination of related perspectives should be a concern in thepossibility of usage. There are many kinds of tools suitable for working with in this phase such as AHP [24]; means end chain [25], mind map [26], and VSA [7].

Phase 3 Indicator Assigning. In this phase, the measurement team starts with determining the indicators of each perspective. Like the outcomes and perspectives setting, not all indicators can beused for measurement. Thus, the measurement team must select the most necessary and related indicators for use. An indicator can be described as through a number of terms, such as quantity and quality progression, time, location, cost and expense. A consideration of this phase is that all of the program indicators will affect the organizational indicators. For example, the measurement program of the Goat/Sheep farm project A measurement analyst identified related perspective, indicator and expected value, as shown in table 2.

In the next phase, the measurement team should define the details of each indicator, including formula, measurement method, scale, unit, data collection and variables; this is shownin Table 3. These elements are very useful in the step of measure selection.

Table 2. OPI elements of the Goat/Sheep farm project

Outcome	Type	Period	Perspectives	Indicator	Expected result		
					Green	Yellow	Red
Staff has expertise in software development and succeed in their careers	Ultimate	3 year	Staff	% of staff who have a jobs in 6 month	100%	90%	80%

Table 3. Sample details of each indicator of the Goat/Sheep farm project

Indicator	Formula	Scale	Unit	Control Variable	Data collection	Measurement method
% increasein the ability to run multiple processes	After training skill - previous skill	Interval	%	1.Size of program 2.Software development phase	Software products in each phase (Usecase, Class, Code)	• Evaluation by trainer • Control testing data using size • Scores from the trainer. • The trainer assigns the score based on productivity in each process of each project

Step 5: Select Measure.

The OPI model is used again to obtain proper measures. There are two main phases: measure collection, and measure identification. Measure collection starts with gathering and dividing measures. There are two criteria: strategy and perspective. Strategy is the method of outcome production. Perspective is a second criterion for dividing measures, After collecting and dividing measures, each measure is evaluated using a variable compatibility scale and unit criteria (OPI's properties). The purpose of this evaluation is to identify candidate measures that fit with the indicators (see on table 3).

The next task is to collect base measures. Base measures are any measures that can derive another measure or controls sample data such as size, complexity etc.; these are base measures that needs to be kept.

Table 4. Sample of the base measure

Measure	Formula	Base measure	Data
Rating score	Summation score in each skill	Defect rate productivity	Defect rate productivity-Trainer 's score

Step 6: Data collection, Measure and Reporting Schedule This step breaks the measurement plan up into a data collection, measurement, and reporting schedule.

Data sources need to be selected carefully. Basic data sources include the following: organization measurement plan and schedule, project plan, software development method, strategy and stakeholder requirement etc. However, the most important condition is that data sources must relateto the contents of OPI. All data sources must serve as materials to produce the information products. Then, these products must produce the outcomes in the higher levels.

Reporting Procedures: this step requires the workers to meet more times to brainstorm and determine a good procedure and reporting schedule. Both software measurement levels and organizational outcome management must support the procedure and reporting. Figures3 and 4show examples of measure and reporting schedules. The schedulesare then followed by the period of the program. The measurement librarian applies this schedule in order to follow the activities. Figure 3 shows the schedule of the My Genogram project thatwas developed by using the waterfall model. Figure4 shows a schedule based on the spiral model.

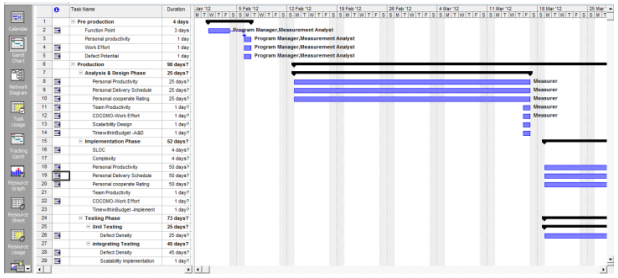

Fig3. Measure and Reporting Schedule based on Waterfall Model: My Genogram Project

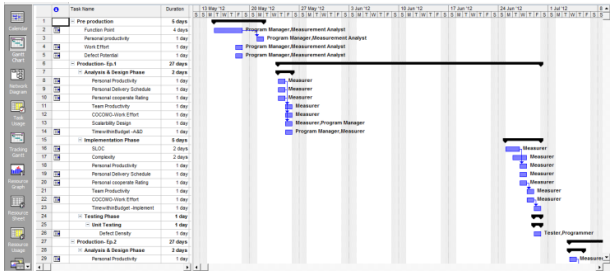

Fig4. Measure and Reporting Schedule based on Spiral Model in TNFC Project

Step 76: Documentations. This section introduces available documentation processes that are used in the SwE laboratory measurement program. At this point, the measurement teams were ready to establish the measurement commitments using the OPI format.

Table 5. List of documents for measurement program in SwE Laboratory

Item	Name	Purpose
MP-V02	Measurement Plan Template	Template for planning the measurement process
OPI-V02	OPI Dashboard	The central template used for management of measurement commitment and information details
ID-V02	Indicator Detail Form	To present further detail about the indicator
MD-V04	Measure Detail Form	To present detail about the measure
DC-V01	Data Collection Form	To present detail about the data collection
KBD-V02	Data Assignment Card	To present detail about the data assignment
KBP-V04	Task Assignment Card	To present detail about the work assignment
PM-V01	Operation Report	A template used to record any problem requests in the operation.

Step 8: Pilot Test. Any new measurement plan should have apre-test. Inevitably, glitches and problems will occur that need to be corrected. Any created plan should proceed with caution in the first round of use. This step has three kinds of test, activities, data and measure. A procedure test examinestheperformance of a procedure that can support the input / output when the requirements have been decided on.Each step of procedure should allow for editing or rework. A measure test is an activity to test the consistency between indicators and measures. The method requires the setting up of sample data. Sample data may refer to a set of data such as source codes, classes, test cases and any set of the system's data. In addition, the measurers may use sample data from the standard data of similar systems orthe predecessor system. Subsequently, the result of indicators willbe compared with all outputs from testing. Good measures should give results that have good compatibility with the indicators.

The measurement teams also focus on data quality. The quality of data affects the accuracy of the results of the measurements. Currently, there are many models for data quality assessment. These models can be appliedin testing data, as seen inA Framework for Analysis of Data Quality Research, presented by Richard Y. Wang, etc.al [27], and S.M.A.R.T Acronyms [20]. In the SwE laboratory, data must be assessed using the dimensional qualities defined by Leo L. Pipino et al. [28].

Step 9: Perform the Measurement. This step is neededto manage the process in order to comply with the plan. Risks or problems that may occur in a process should be monitored and solved and the plan improved. From experiences showed that documentation and a good workflow management could increase the success of a measurement plan. Moreover, any problems will be recorded using a PM-v01 document in order to detect and solve all mistakes in the process. This has the result of improving performance in each measurement cycle.

3.3 Analysing the Information Products

This section examines the information products and stores and produces reportsaccording to schedule.

Step 10: Examine the Information Products. The measurement team validates the information products thatare produced from each measure. The measurement team should determine various errors, such as omission of some measures or incorrect results.

Step 11: Store and Produce the Report. The information product will be stored or reported base on the report schedule. SwELaboratory divided the schedule into many sub-schedules with the aim to simplify visual management. However, the big picture must also be considered in the program schedule. The program manager will use the program schedule and report schedule to control report production.

3.4 Using the Results

This section focuses on how information products from software measurement can be used to improve the operation. For every report, the measurement team must evaluate the result of the usage. The evaluation result will be usedto improve the measurement plan for the next cycle. In addition, it can be used to produce an experience report; the knowledge in this report could allow for more efficient production in the next program. SwE Laboratory operates every project based on PDCA, so every project will be planned, donechecked, andactioned every time.

4. EVALUATION METHODS AND RESULTS

4.1 Evaluation methods

The evaluation started in the fourth quarter of 2010; the author operation record (PM-01) was kept by observation and through the use of the interview tools. In 2011, SwE Laboratory defined the framework and tools to use in the My Genogram and TNFC projects. In 2012, the framework was improved and applied in the Goat/Sheep farm project. These records were compared with two projects that did not feature transformation of organizational outcomes. There projects were the Postal system and Health Centre system.

4.2 Evaluation Results

The evaluation results in this paper follow the two objectives thatwere presented in the above section as follows:

Objective 1: To show that the framework can controls consistency between the software measurement process and organizational outcomes measurement.

These evaluation results present the consistency between software measurement results and organizational outcomes. Based on the operation record (PM-01), it can define a responsiveness of the framework to indicators of five types, as follows:

1. The measurement result does not correspond to the target indicators

2. The measurement result does not correspond to the indicators, but there have been additional measurements taken.

3. The measurement results correspond to some part of target indicators, with no re-running o[17] f the measurement.

4. The measurement results correspond to some part of indicators, but there has been additional re-running of the measurement.

5. The project measurement results completely correspond to the indicators.

From the above-mentioned projects that were driven by the transformation framework, type 5 had the highest frequency at 60% of the problem records. Type three and four were lower at only 15%, and types one and two had the lowest frequency of 5%. Conversely, projects that were not driven by the transformation framework had almost double the proportion of type two and type four with 44% and 22% respectively. Type three (11%) was lower than type five (12%). Finally, type one had a frequency of 5%.

Objective 2: A transformation framework is an effective tool to transform the organizational outcome and its indicators to a software measurement process.

This part applied an interview and observation tools for collection of data from the records. From problem and comment records, the framework can reduce the time required to re-running of the measurement in an organizational measurement process. A comparison between the Goat/Sheep farm and Health Centre systems found that the health centre system had three indicators that required re-running of the measurement,while the goat/sheep farm did not need to have any re-running. Re-runningof the Health Centre system took four days to collect data, createan examination, measure and summarise. The results of the Health Centre system were consistent with apostal system that used 10 days for re-measurere-running . Another problem of the Health Centre system is report production, because the measurement plan of this system is not synchronised with the organizational measurement schedule. However, the Health Centre system spends less time for the collection of data and designing the selection plan than the Goat/Sheep farm project.

For the other part of the evaluation, this paper used a questionnaire with core organization management, including three instructors and two researchers. The questionnaire was also appliedto the measurement team in each project, which consisted of members in core organization management and six staff members. The objective of the evaluation is to evaluate the usability of the framework. The results show that about 73 % of members accepted that the framework fully improved the transformation of the organizational outcome into the software measurement process. 27.27% of the members accepted this framework as normal.

5. CONCLUSION

The existing software measurement programs sometime may not produce the information products that are needed by business evaluators. As a result, an organization's outcomes may not be assessed by only the results produced by programs. One solution to the problem is to put the outcomes as parameters to their related measurement programs. However, the outcome to program transformation process is a complex task. This paper proposes a novel framework to simplify such process. The framework applies the OPI Model, balance scorecard, twelve key steps and ISO-15939 as tools to perform such transformation. The result of this framework is a measurement plan that can produce information products that can be used by both software developers and business evaluators. The three-year experiment, during 2010-2012, to test the performance of this framework is set up at SwE laboratory, Walailak University, Thailand. Data collection consists of survey, observation, comparison, and interview members of the laboratory. Five projects are used as samples of the experiment. Three of them are conducted under the proposed framework. In the term of consistency with the outcome, the results are shown that chosen projects are more consistent. For efficiency, the point that is evaluated is the average time needed to re-run the measurement. The result is shown that the time is 5.33 day decreased. The user satisfaction test is considered good since 72.73 % of the laboratory members are satisfied to the framework where the rests think that they are neutral.

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