An Empirical Study of Process Management and Metrics based on In-process Measurements of a Standardized Requirements Definition Phase

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Abstract. This paper focuses on in-process project measurement in the requirements definition phase based on progress with standardization of this phase. The authors have verified the utility of in-process project measurement in a real mid-scale multi-vendor distributed project. This trial was successful, but limited to a part of the total development process. The project measurement target was limited to later processes such as the coding and testing phases where the output products were easy to acquire. The requirements definition phase where process and product were not standardized was difficult to measure. However, a newly provided governmental process guideline standardizes the process and product for the requirements definition phase, and the authors had an opportunity to measure such a requirements definition effort. This paper presents an empirical study of in-process project measurement in the standardized requirements definition phase, verifies the usefulness of this measurement for project management, and reveals the possibility of creating a new software metrics field using these measurements.

Keywords: Empirical software engineering, Software process measurement, In-process measurement, Enterprise Architecture, Requirements definition phase measurement.

1 Introduction

This paper starts by describing the authors' previous project measurement efforts that target downstream processes following the design phase. Then it explains how the Japanese government guidelines using Enterprise Architecture (EA) methods standardize the process and products in the design phase, making measurement of this phase possible. Finally, the paper outlines the target project using the EA method. It provides descriptions of the process and project measurement methods used in the project, the measurement results, and observations about the usefulness of these measurements and possible extensions of software metrics based on this study.

2 Motivation of this study

This section outlines the previous in-process measurement work as background for the authors' current study. The authors have previously verified the usefulness of in-process project measurement and feedback to project management in development [1][2]. In the software development process, the authors had focused their interest on design, coding, and testing phases and had separated the measurement targets into two categories such as basic targets and extended targets.

The basic measurement targets are the amount of description products for each phase. The basic analysis targets in the coding phase are the number of transitions of description products. Concretely, these are the numbers of additions, eliminations, and modifications of the descriptions. In the testing phase the numbers of detected faults and the numbers of corrections, along with the numbers of transition are measured.

The extended measurements in the design phases measure the amount of design and design review materials and analyze the transitions in that amount. In the coding phase, the measurement targets are source code entities and their modification histories. In the testing phase, various fault reports are measured. Also, fault cause factors and fault related phases are analyzed.

This empirical study combined the measurements and analysis to provide feedback to the project management. This produced positive effects for the project. Based on the success of this research, the authors wanted to expand in-process measurement to the "requirements definition" phase and to develop a complete lifecycle measurement method for processes and products across the full development process.

3 Characteristics of the "Requirements Definition" phase

3.1 The Requirements Definition Phase and EA Method

Empirical study and measurements of requirements definition phase has been difficult because there are various methods and tools used and there is relatively little standardization. However, the use of the Enterprise Architecture method in Japan makes it easier to measure this phase.

The Enterprise Architecture is a total methodology for enterprise information system development, arranging the organizational business and information systems to provide overall optimizations. It is based on Zachman's framework [3] and constructed from various proposed design and management methods.

Practically, the EA method consists of three phases, the AsIs, ToBe, and policy arrangement phases. The AsIs phase describes the present state of the target system. The ToBe phase designs the future ideal system. The policy arrangement phase, between the AsIs and ToBe phases, makes decisions about policies for optimizing the business and systems. A special feature of the EA method is that it defines many standardized hierarchical diagrams for the AsIs and the ToBe phases to increase the mutual understanding between target system stakeholders.

From the viewpoint of project measurement, it is easier to expand project measurement methods from the development phase into the requirements definition phase because the EA method has standardized process and product formats. The in-process measurement can use the amount of descriptions and the transitions in diagrams in the AsIs and ToBe phases, such as the total number of diagrams, along with additions, eliminations, and modifications of diagram elements. Section 4 describes such an empirical study.

3.2 The Japanese Government's EA Guideline

In 2003, the Japanese government provided an EA guideline for the requirements definition phase to reconstruct and optimize government business and information systems [4]. This guideline provides basic architecture, reference models, and EA products in a four-layer structure of Business Architecture, Data Architecture, Application Architecture, and Technology Architecture for the AsIs and ToBe phases. It provides three phases, AsIs, Optimize, and ToBe, as the project process architecture. It recommends that the management approach use Earned Value Management (EVM) and the Work Breakdown Structure (WBS) method. In the AsIs and ToBe phases, the requirements definition uses four kinds of diagrams: The Damond Mandala Matrix (DMM), Data Flow Diagram (DFD), Work Flow Architecture (WFA), and Entity Relationship Diagram (ERD). These diagrams are illustrated in Fig. 1-1 to Fig. 1-4.

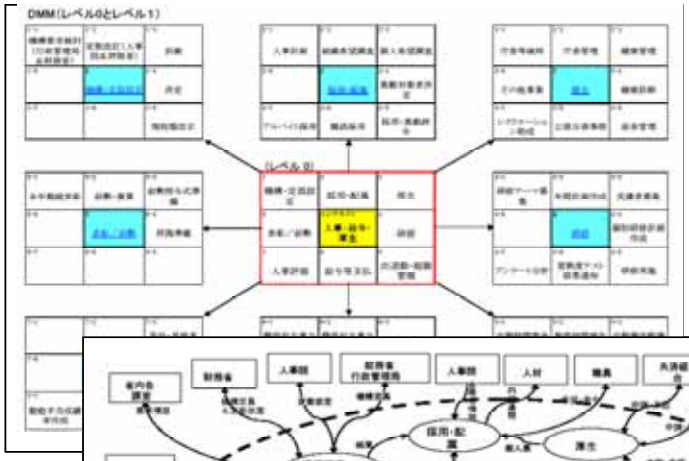

Fig.1-1
Diamond Mandala
Matrix (DMM)

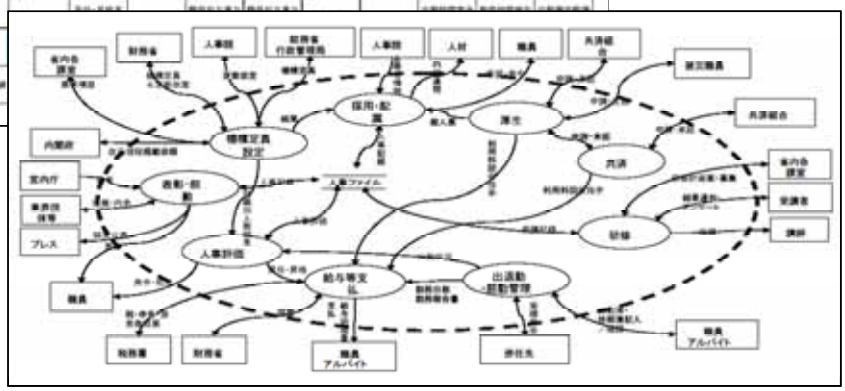

Fig.1-2 Data Flow Diagram (DFD)

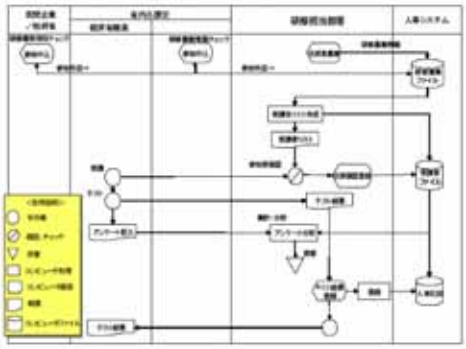

Fig.1-3 Work Flow Architecture (WFA)

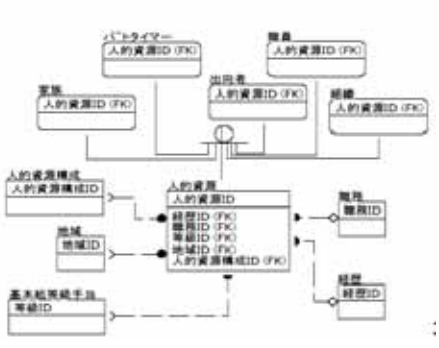

Fig. 1-4 Entity Relationship Diagram (ERD)

The authors had an opportunity to measure the requirements definition phase of a middle-scale governmental project based on EA methods. This project started in August of 2006 and finished its requirements definition phase in March of 2007.

The next section provides a report and evaluation of the empirical study.

4 In-process measurements of an Enterprise Architecture project

4.1 Outline of the Target Project

The target project is a plan for business and system optimization of the Information Technology Promotion Agency, Japan (IPA) [5], a subsidiary organization of the Ministry of Economy, Trade and Industry (METI). This project includes four systems (Businesses A to D) such as a total business management system for a business organization of about 200 employees. IPA staff and a business consulting company accomplished the requirements definition work in a collaborative manner. The goal of the project was to provide requirements definition and an RFP for development process procurement. By government policy, the development phase should be procured from another software company.

This project produced 34 kinds of documents including 29 diagrams as shown in Table 1. The planned document types were different for each business application because the development phase schedule depends on each business.

4.2 Project Measurements

This project used the following in-process project measurements:

1) Weekly measurement of four types of diagrams: DMM, DFD, WFA, and ERD (18 diagrams total, shaded part of Table 1).

2) Interviews of the project leader with a checklist to obtain project context information, a method that was useful in the previous development process measurement study. Also, an interview to the leader after the project finished.

Table 1 Outcome Diagrams & Management Targets

Target Business	A		B		C		D	
AsIs/ToBe	AsIs	ToBe	AsIs	ToBe	AsIs	ToBe	AsIs	ToBe
Business Description	x		x		x		x	
DMM			x	x			x	
DFD	x	x	x	x	x	x	x	
WFA	x	x	x	x			x	
ERD			x	x			x	
Information System Reference Diagram			x	x			x	
Network System Diagram			x	x				
Software System Diagram			x					
Hardware Structure Diagram			x					

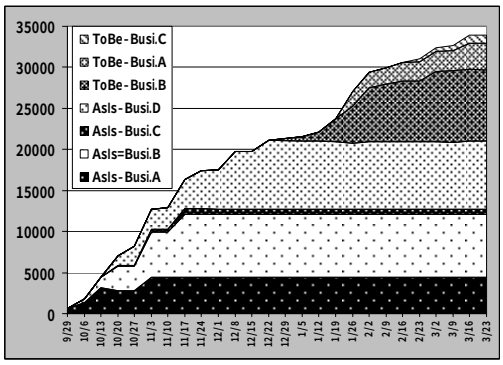

Fig.2 Diagram Elements Stack of all Business

3) Attending the project meetings to get context information, also useful in the development process study.

The measured diagrams were written with an EA tool constructed on Microsoft's drawing tool Visio. The Visio reporting function was used to measure the number of diagrams, including the number of sheets, diagram elements, and transitions. While the measurement process included some manual work, it was mainly done automatically. The 18 documents were selected for study because there were very little other content and few other documents, suggesting that these 18 documents represent the total process outcome for this project. Also the reflection of project context information from 2) and 3) activity is considered very important.

4.3 Requirements definition Phase Measurement Results

In 13 weeks, the description of the AsIs diagrams was completed for three businesses and other one was completed in the end of May 2007. ToBe diagram description for three businesses was started January 2007 and finished by 11 weeks work.

During this process, the following measurements and graphical visualizations were made:

1) The amount of diagram description and transitions measured in number of sheets, both total amounts and for each business

2) The number of diagram elements and diagram connector elements in the diagrams and their transitions, measured as total amounts and for each business

3) Changes in the numbers of diagram files through addition, elimination, and modification, both total and for each business

4) For each diagram in each file, measure the addition, elimination, and modifications of elements by counting text strings on the diagram elements.

5) Weekly described amount of diagram transitions by number of sheets, diagram elements, and connector elements, both total and for each business.

Fig. 2 to Fig. 8 shows examples of these measurement results in graphical form. The following trends are directly read from those graphs.

Fig. 2 shows changes in the described diagram elements with the cumulative stack of each business during the 24 weeks. In total, about 730 sheets, 34,000 elements were described. This graph shows not only the total amount project proceeding

process for each business but also description documents amount, working start timing and finished stable situation.

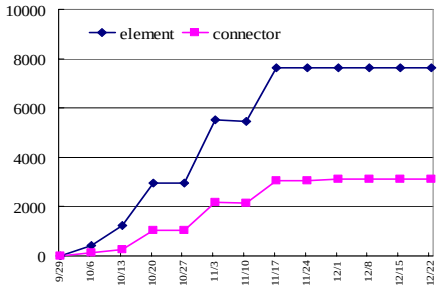

Fig.3 Diagram Elements of Business B (AsIs)

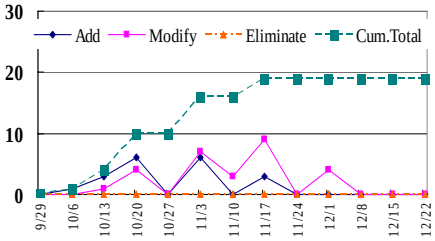

Fig.4 File Number Transition of Business B (AsIs)

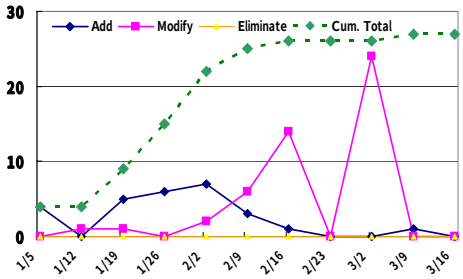

Fig.5 File Number Transition of Business B (ToBe)

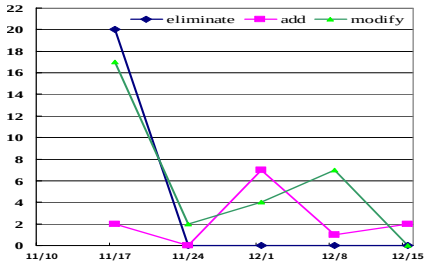

Fig.6 Diagram Modification in one file Example (8 sheets)

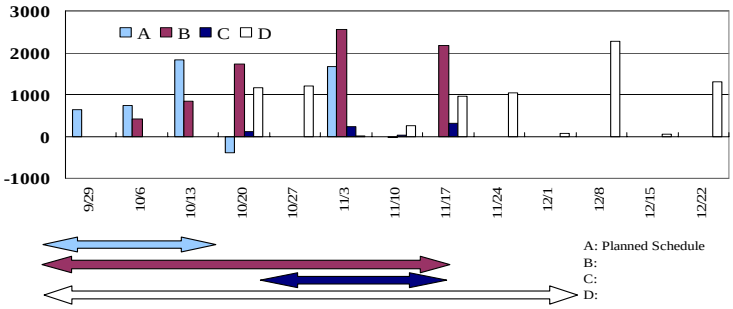

Fig. 7 Weekly Addition of Diagram Elements (AsIs)

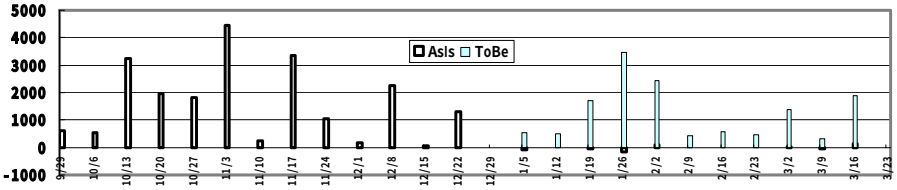

Fig.8 Total Weekly Addition of Diagram Elements (AsIs and ToBe)

Fig. 3 shows the number of AsIs described elements for business B. This study illustrates the data for each business. Fig. 4 and Fig. 5 show the file number status of AsIs and ToBe phase of Business B. It could see that AsIs phase was smoothly progressed to stable and ToBe phase was rather rapidly progressed. Fig. 6 shows all changes of one diagram file consisting of eight diagrams including in 6 weeks. From this figure, the trend appears to show that this area's AsIs description work is gradually stabilizing. Fig. 7 showed changes in the amount of description on a weekly basis in AsIs phase case. From this graph, it is clear that the description process for the four businesses were executed shifted a few weeks. Fig. 8 shows the total changes on a weekly basis. The amount of work performed can be cleared from that figure.

5 Evaluation and Study of the Measurement Results

5.1 Comparison with official progress report

Based on the governmental EA guideline, the target project is managed with EVM and WBS methods. The official progress report is based on declarations by the participants. Fig. 9 is an example of the EVM report. This report shows the consumed human resources, but it is not clear about the situation of the outcome amounts. Fig. 10 shows the WBS declaration level progress report visualized by authors. In the WBS method, the work in progress is reported through detailed activities. However, the granularity of this report is very rough. There is no information about the amount of outcome produced. The WBS based report is based on declared progress estimation criteria. This reporting is also limited by self declaration and human intervention. For example, in some case progress raised rapidly to 80% but after that it remained stable for a long time, or in the other case, in the EVM chart, during a long period progress was delayed but when the deadline was coming it progressed rapidly and finished on time.

Compared to these official reports based on self-declarations, the product measurement method tried in this study presents detailed information with high granularity based on real amounts of outcome products. This information is based on the raw data of the production, so human intervention does not affect it. For example, Fig. 7 includes the declared schedule of work. From this graph, gaps between the declared schedule and the real work progress based on actual product information are clearly visible.

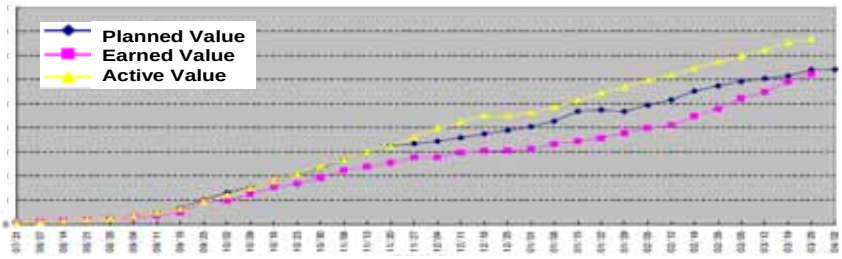

Fig9. EVM Report

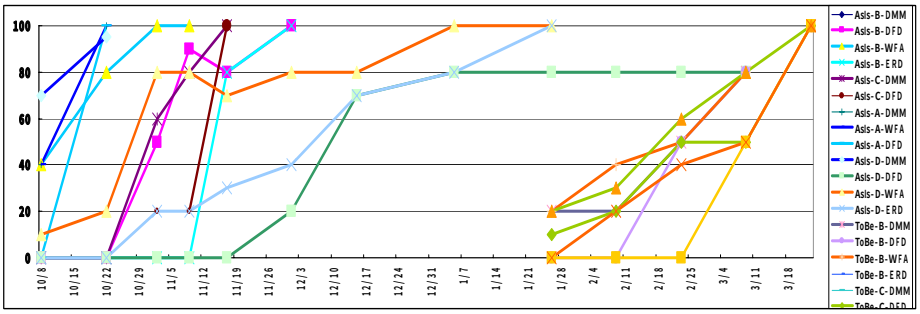

Fig. 10 Declaration Level Progress Report (AsIs & ToBe) (%)

5.2 Study for new software metrics possibility

The target system for measurement in this study is not very large, but during 24 weeks, this work included over 700 diagram sheets with over 30,000 diagram elements. Considering analogies between measurement targets such as diagram sheets or numbers of diagram elements and program modules or source lines of code (SLOC), we can propose developing new software metrics for the requirements definition phase. These new metrics are expected to contribute to increasing the productivity and quality of software development processes in the same way as other existing software metrics. For example, it is likely that 30,000 diagram elements are analogous to 30 Ksteps of high-level programming language code, the number of diagram sheets can be compared to the number of program modules, and the number of diagram file as corresponds to the number of program files.

For example, Fig. 11 illustrates diagram element numbers per working effort. As other metrics, working effort per sheet, working effort per diagram element, numbers of sheets per working effort were considerable. Working effort can be converted into cost.

This trial is based on one project case study but comparing seven business works we can see differences in working density. For example, productivity depends on each business. Both businesses A and C had fewer products but their productivity shows different trends. In the case of business A, it was easy to understand business process, so it showed high productivity but in the case of business C, the business process was highly complicated, so low productivity was shown. This trend is not same as the general trend in the development phase measured by SLOC and Function Point (FP). In the development phase, generally larger development has lower productivity.

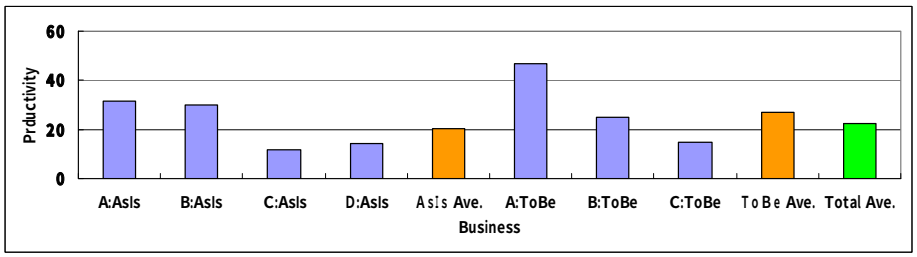

Fig. 11 Diagram Elements per effort

5.3 Possibility as a software benchmark data element

As previously suggested, from the viewpoint of software metrics the number of diagram elements in the requirements definition phase of the EA method process is strongly analogous to SLOC in the development phase which has meaning for project measurement based on description of the number of transitions.

Various meanings are included in source code and the definition of SLOC is not so strict, but SLOC is often used as an important base for software metrics. For example, in Japan the "Software Development Data White Paper" published every year by the IPA Software Engineering Center includes benchmark data for over 1,000 projects, and shows 213 kinds of analyzed results [6]. In this analysis 75 cases relate to Function Point (FP) and 70 cases relate to SLOC. Comparing SLOC, definition of FP is strict but it is rather static data in software development process and unsuitable to in-process measurement. While SLOC definitions may be imprecise, it is dynamic data in software development and useful for in-process measurement. Similarly, the number of diagram elements will be a useful base for metrics in the requirements definition phase analogous to SLOC in the development phase.

For example Fig. 12 shows cost per element in relative form. (Average is 1). This value varies widely depending on the business. There is difference in AsIs and ToBe. In two businesses, AsIs was higher than Tobe and one business was opposite, and totally ToBe had higher results. This phenomenon was different from the general trend. Generally AsIs phase is easier than ToBe phase, because this work is based on current status of business systems, but ToBe is rather complicated work to design future ideal system. So from this result it is concerned quality of ToBe work. And about ToBe process of business B, it is suggested that this work was done carefully. Also from Fig. 9 and Fig. 10 it appears that the ToBe process was completed rapidly to fit the deadline of project.

This single case study suggests various possibilities for project measurement.

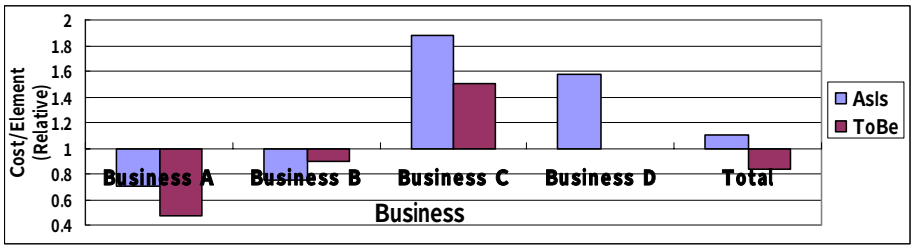

Fig. 12 Cost per Diagram Element (relative value)

6 Future Study

This trial had little direct reflection of the measurement results in the project management because this project was planned using traditional management methods with WBS and EVM and these measurements were only additional information. But the measured and analyzed data were useful for managers like the authors who don't

have direct access to the real working field. Real evaluation of target project will be clearer at the downstream process.

As in Section 2 shows, these trial measurements remained mostly in basic measurement. Various measurement targets remain in extended measurement. Future studies should look at:

1) Collecting quality related data such as review report.

2) Collecting user work (effort) data because requirements definitions phase work are collaborations of user and vendor. It is necessary to measure the total effort to evaluate effectively the total project.

7 Conclusion

This paper presented an empirical study of process output products measurement in the requirements definition phase where it had been difficult to perform measurements because the process and product were not standardized. The Japanese government standardization of the requirements definition phase using the Enterprise Architecture (EA) method makes it possible to perform various measurements and analyze progress in this phase based on empirical data.

In this trial, the measurement of output diagrams and transitions provided a useful way to characterize project progress. These results suggest that the measured data in the requirements phase can be used in a similar way to SLOC in the development phase, creating a new software metrics field.

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