An assistance method of incorporating quantitative management indicator into software development process

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Abstract
In this article, a framework to assist systematic incorporation of quantitative management indicators into software development projects is proposed. We first present a preliminary survey of industrial projects that has been conducted in an enterprise-system division of a software industry in order to investigate dominating factors to indicator selection and utilization. EPDG+ (Electronic Process Data Guidebook Plus) system is designed based on the result of the survey. EPDG+ is a supporting tool to help process tailoring in selection of indicators, integration of measurement and analysis activities, and confirmation of resulting project plans. Through the prototyping of EPDG+, we confirmed the effectiveness of the system to novice managers to select and customize quantitative management plans according to the project profiles such as business areas or project size.
Keywords quantitative management, process guidebook, software process improvement

1. Introduction

Quantitative management, i.e. quantitative controls in both of quality management and schedule management is a key factor in process improvement frameworks that enables exact identification of risk factors and adequate control decisions. Quantitative management requires well-defined indicators derived from quantitative data that is measured or collected in the processes. Number of lines of code (LOC) is a typical example of quantitative data that is collected through coding phase, and a graph plotting the collected LOC data is a typical example of indicator to determine the progress of coding phase.

Generally, we need to select the indicator according to the property of each project, and we also need to appropriately plan activities for measurement and analysis of quantitative data. In CMMI[1], these activities in the software process are categorized in two process areas, “Quantitative Project Management (QPM)” and “Measurement and Analysis (MA)”. Organizations in a certain level of capabilities (e.g. CMMI level 3) usually have their own set of indicators for the project management. It means that the planner must 1) understand the aim of each indicator, 2) select/reject it according to the property of each project, and 3) plan the measurement and analysis activities. However, this task is very difficult for novice planners and novice practitioners because they don’t have sufficient knowledge for using indicators and collection/analysing data that is required by the indicators. As results, novice practitioners may not properly collect quantitative data. They also may derive indictors in wrong way, or novice manager may misuse derived indicators.

In this paper, we focus to such problems in partitioning quantitative management. We first report a survey about the tendency of used indicator in a software development division in Hitachi. The survey was conducted in order to discuss the features of the EPDG+ (Electronic Process Data Guidebook Plus) system that is currently developed at Software Design Laboratory of Nara Institute of Science and Technology (NAIST). EPDG+ targets novice project managers to plan/perform the quantitative management of software development projects. EPDG+ has a feature to recommend appropriate indicators extracted from organizational standard indicator list according to properties of each project. EPDG+ also supports integration of activities for measurement and analysis, which are required by the selected indicators, into an engineering process at project planning.

2. Related study and frameworks

Many works related to quantitative management have been done. In the area of software engineering, quantification of various property of software itself was broadly studied as “software metrics.” Those are mainly focusing to the product quality, not so much for process management.

ISO/IEC9126[2] defines the measure for measuring overall software quality. It classifies the software quality into six quality characteristics, such as functionality, reliability, usability, efficiency, maintainability, and portability, and shows the property by which each is characterized. Furthermore, it also show the data for measuring each quality characteristic directly or indirectly, but does not specify the details of those concrete measurement methods or practical use methods.

On the other hand, ISO/IEC15939[3] about a software measurement process shows the framework for measurement, analysis, and construal to achieve various information needs, such as project management and quality assurance. In this standard, structure of information handled in measurement and in analysis is specified as a reference model as shown in Figure 1.

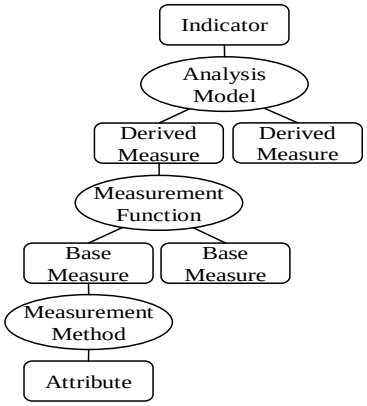


Figure 1 Structure of the ISO measurement information model

This model show the way which makes easy objective decision making based on quantitative information by associating well measurable attributes characteristic to process or product in a project, such as development scale, effort, and number of defects, with the indicator for decision making[4]. Thus, the primary data called "base measure" is collected by quantifying various attributes which exist in a project according to the defined measurement method. The secondary data called "derived measure" is derived by assigning some base measures to measurement function. Finally, the indicator is obtained by analysing these measures according to the defined analysis model. A project manager makes decision according to the finally derived information product with decision criteria. At the following discussions, we use the concept and the term based on ISO measurement information model.

3. Tailoring support for quantitative process management

3.1 Precondition of the approach

In this study, we consider software development organizations, which perform following two practices, as targets of our approach to support quantitative management planning.

- Every project is planned and performed based on the standard development process which is defined as organizational standard, typically, in the form of WBS (Work Breakdown Structure).

- The indicator set for quantitative process management is prepared as an organization standard.

Table 1 shows an indicator "*the review speed*" as an example of standard indicator in a certain organization in Hitachi. As seen in this example, in many organizations, the definition of standard indicators is concisely described in the natural language, and almost none of strict explanation about an analysis model, functional definition (e.g. calculation formula), or a measurement method are given.

3.2 Needs for support in the process tailoring

In quantitative management, a manager has to select required indicators according to the characteristics of a project and integrate associated measurement activities into a process description of the project. However, tailoring guideline is not clarified in many organizations, and the difficulty is attended for the planner, especially for the inexperienced planner, because he/she has to judge the characteristics of a project appropriately when selecting the indicator to be used.

Besides, more the scale of the project and the number of employed indicator grow, more relations among indicators and measured values gets complicated. As a result, understanding and confirming the

Table 1 Example of the Indicator Definition used in a Software Company

#	Name	Purpose	Analyst	Required Measurement	Collector	Measuring Method
2	Review speed	To define the terms for efficient review	Project manager	A: Target size B: Review time	A: Reviewer B: Reviewer	A: Measuring the size of target product B: Measuring spending time

management plan also becomes very difficult. For example, when the indicator “review speed” shown in Table1 is employed to a project, 1) how and when to use “review speed” and 2) how and when to measure “review time” and “target size” required by “review speed” are specified based on planner’s or manager’s experience and knowledge. Therefore, proper use of indicators and exactness of measured values highly depend on individuals who concern management and measurement activities.

4. Survey of the current tendency of indicator use

In order to consider a detail of indicator recommendation feature which supports selecting, it is important that recommended indicators fit to the context of the target project. At first, we have enumerated several criteria for recommendation based on such as CMMI’s process area, an estimated size, a target business area, and etc. For more concrete discussion about project-specific criteria, we also surveyed the current status of used indicators for 17 projects in a software development organization in Hitachi.

4.1 Outline

The survey was conducted by using the questionnaire for project managers who apply quantitative management in a software development organization (enterprise software system development section) with hundreds of employee. We sent the questionnaire to them in the company mainly asking about actual use of their organizational standard 45 management indicators. They are used for management of progress, review, testing, process quality assurance, requirement management, acquiring, and configuration management.

The first part of the questionnaire is questions about the profile of the project, such as project size, business area, and profile of the manager, e.g. months of experience as project manager and the number of project s/he ever managed. The second part (main part) is a list of indicators; for each indicator, questioner is requested to specify the extent of use. The extent of use is at first categorized into two answers, “Used” or “Unused”. Then each answer is divided in to more detailed ones as shown in Table 2. In addition, the reason that had was used or not used was optionally answered.

4.2 Results and analysis

At first, we summarized the results simply in two categories, used or unused, to get rough trends of the answers. In spite of our expectations, there is no significant difference or tendency of indicators use according to the scale of the projects (see Figure 2). However, use rate of every category of indicator differed significantly as follows;

- Indicators for progress tracking are used in most projects. These indicators are regarded almost mandatory by most projects.

- Indicators for process quality assessment are employed by a few projects because this organization started PQA activity a few years ago with selected projects. Moreover, several projects are completed more than 5 years ago.

- Indicators for review tracking, for risk management, for acquirement control, and for configuration management showed low rate of use. The reasons for these tendencies were not clear at this point.

Table 2 Enumerated level of used/unused for an indicator

Used	1.Mandatory	The indicator is always used as is in this kind of projects.
	2.Optional	The indicator is not always used but used as is for this project.
	3.Modified	The indicator is used but modified to fit the circumstances of this project.
	4.Formal	The indicator is employed just for the formality.
	5.Other	The indicator used in some reason different from above.
Unused	1.Disused	The indicator is not used in this kind of projects.
	2.Obscure	The indicator is not understood well and therefore not used.
	3.Expensive	The indicator costs too much to be used in this project.
	4.Not Ready	The environment for this project is not prepared to use the indicator.
	5.Other	The indicator not used in some reason different from above.

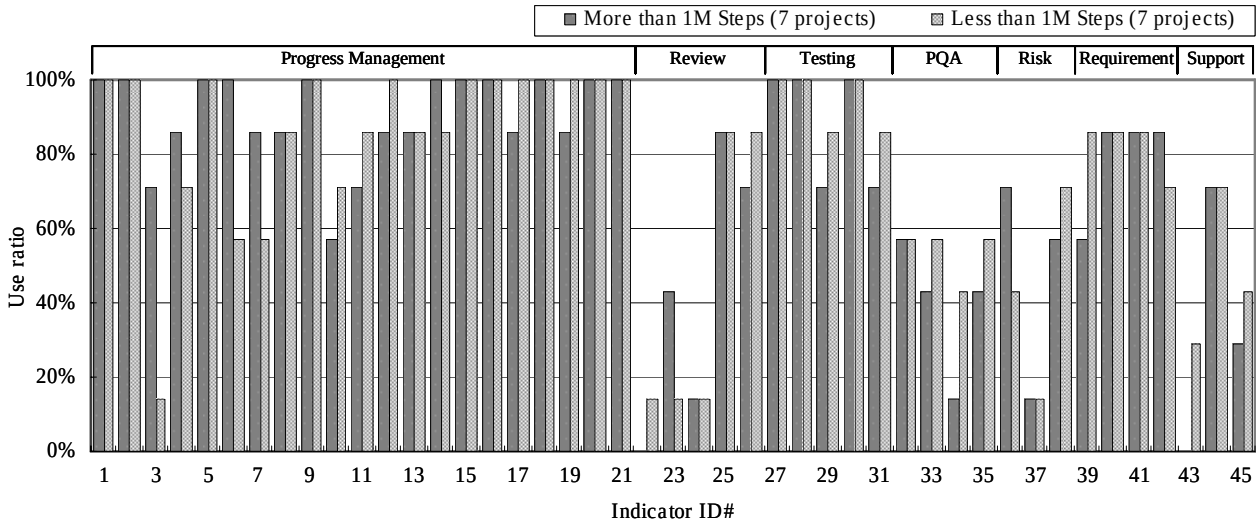


Figure 2 Summary of the use ratio (used vs. total) for each indicator

Then we proceed to detailed analysis according to product size (less or more than 1M steps) and manager's experience (less or more than 4 years) also regarding level of indicator use. In order to proceed to this level of analysis, we had to exclude 4 samples because they don't have product scale information in program steps and couldn't be categorized. Therefore we used 13 project samples in following analysis.

The detail of the tendency of the indicator use in both size and experience are summarized in Table 3. Table 3 shows summary divided in two parts for small sized project's data and large sized project's data. Each part consists of two areas; left and right areas are for inexperienced and experienced managers' answers respectively. One line of the table is for one indicator, and each cell contains the number of answers. For example, Indicator #1 is employed as "mandatory" by 3 novice managers of small projects.

Main reason why we made this summarization is that we assume novice managers of small project need EPDG+'s help to select and adapt provided indicators to fit the size of the project, meanwhile most indicators will be employed in large projects regardless of the experience of the managers. We currently have following observations:

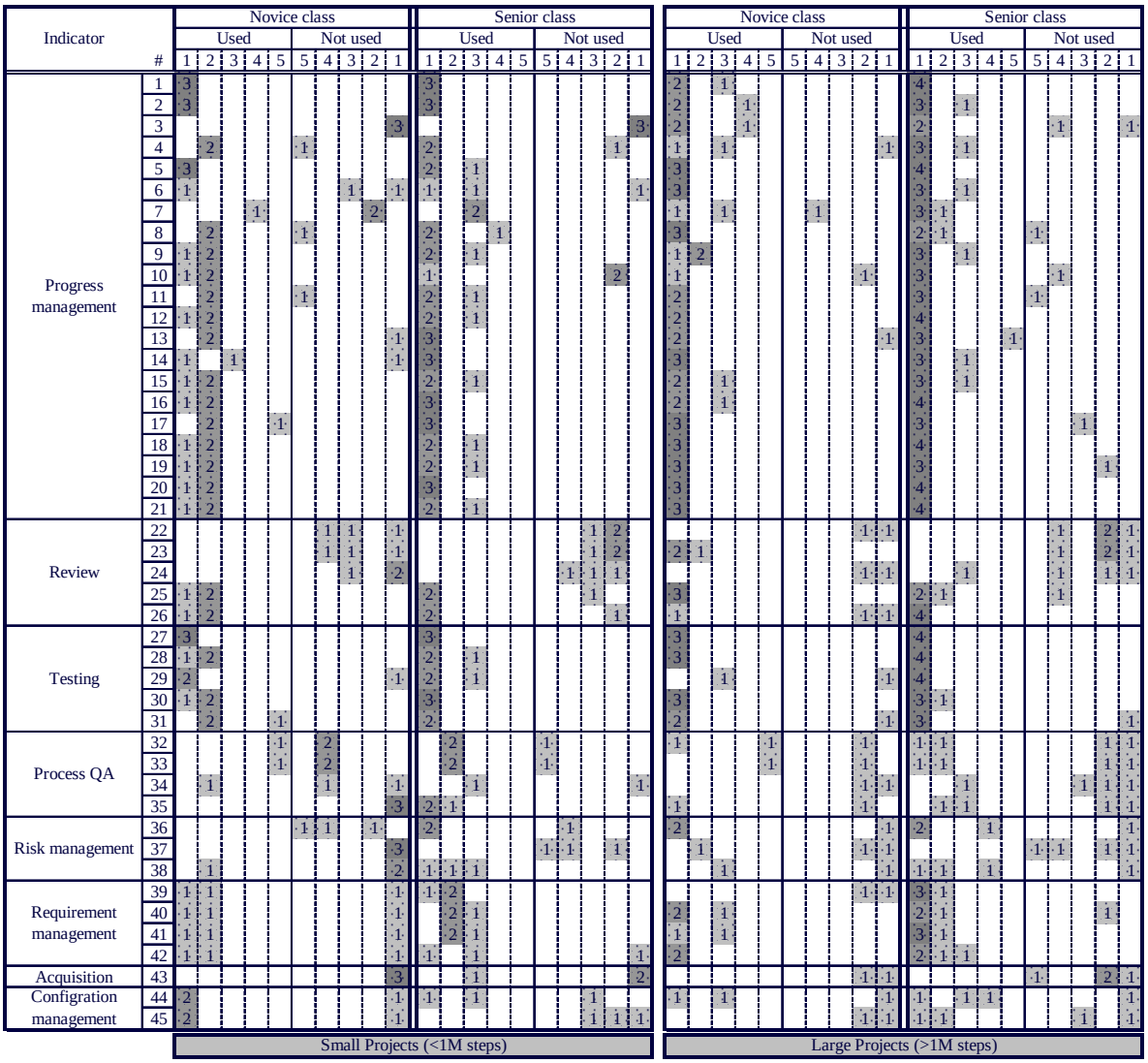
- In the small project group, experienced managers' use of "modified" indicators in various indicator categories is observed, while novice managers seldom do such adaptation. We found a comment from questionnaires that experienced manager often use alternative information that is easy to capture, and they also omit some management objects or tasks according to their practical situations. Therefore, we can assume that experienced managers have the knowledge of equivalence/similarity and measurement cost of information used for management, and they reduce cost of the quantitative management using such knowledge.

- In the small project group, indicator #3 is not employed by all projects as "disused" while in the large project group; most projects use this indicator as "mandatory". Indicator #3 is for tracking the delay of progress report meetings and customer meetings. Therefore, this is natural because having meeting on schedule is not difficult for small projects while large projects having more stakeholders have more possibility of the delay of meeting. In other words, this indicator can be omitted in small projects in this organization.

- In both of the small and large project groups, indicator #22~24 are not employed by any projects. Furthermore, a few experienced managers answered that they don't sufficiently understand the definition or usage of those indicators, and therefore they don't use them. These indicators are to track the conditions of review (such as preparation time or review speed) and review results (number of collected defects) as they are designed for the improvement of review task.

We assume the reason why these indicators were not used is that they are not traditional indicators in this organization and therefore the usefulness of the indicator is not widely recognized, and also that they are not regarded to be useful for individual project as the aim of the indicators is improvement in the future.

Table 3 Summary of the tendency of the indicator use categorized project size and manager experiences



4.3 Discussion

Our survey shown above just provides as-is of one organization's indicator use tendency, and we need to be careful to generalize derived observations without further justifications. However those observations are still valuable to consider the systematic support to selection and adaptation of indicators. From a view point of designing EPDG+ features, following possibilities were worth to consider:

1. Modification made to standard indicators by experienced managers may be exposed to inexperienced managers as supplemental information of management planning. In order to accomplish this feature, function to customize the definition of standard indicators, function to store them for future reuse, and function to expose accumulated alternative indicators must be implemented.
2. As we confirmed that the indicator #3 is not required for small projects, contexts of the project influence the use pattern of the indicators. By extracting influenced patterns according to various project contexts, we will be able to provide indicator candidates to be employed in pattern-oriented ways. In order to accomplish this, further survey to more projects and more organizations are needed.
3. By accumulating the record of modification to standard indicators and standard process, EPDG+ system itself will make this kind of survey quite easily and inexpensive.

Meanwhile, several EPG (Electronic software Process Guidebook) systems are proposed in the past (e.g. [5]). Most of them mainly focus to support understanding of the prescribed software process. Our EPDG approach is also capable to this field, but our current focus is how to utilize the information models, such as definition and flow of quantitative data, required by quantitative management. The information models are useful and very important for the process tailoring, as we have shown in this paper.

5. Process tailoring support system EPDG+

The EPDG+ (EPDG Plus) system is an extended version of EPDG (Electronic Process Data Guidebook) system[6] which is formerly developed into our group. EPDG is a web browser-based system to help managers and developers refer to information about indicators and measured values such as its definition, attributes and a measuring method. The EPDG scopes to help understandings of process data definitions for analysis by manager and measurement by developer.

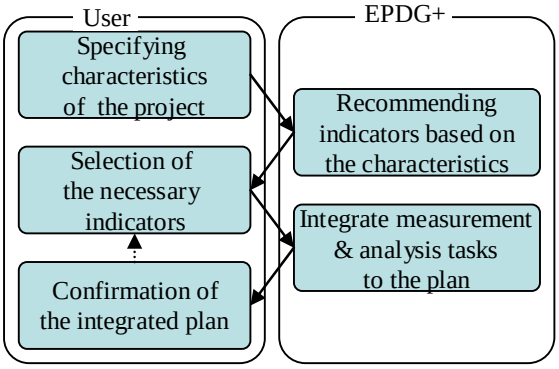


Figure 3 Typical use scenario for process tailoring support system

On the other hand, EPDG+ targets project planning enacted by planner. It supports a tailoring in planning measurement and analysis activity plan depending on the characteristics of a project based on quantitative management.

5.1 Tailoring support features

Tailoring support is typically provided according to the scenario shown in Figure 3. In this scenario, the work flow is assumed that the planner inputs a process description without management plan, integrates management plan based on quantitative management, and then outputs a process description with management plan. In the following, referring to Figure 3, we describe an operational flow of the system from a user (planner)'s viewpoint.

1. A planner executes the system and inputs a process description, and then specifies profile (characteristics) of the project.
2. Referring to the indicators that the system has exposed to the planner, s/he selects indicators regarded to be necessary for the project. At this point, EPDG+ can provide indicator candidates to be used in the project in various ways, such as grouping based on process area of CMMI, project's profile (size, category, language, etc.) or specified management categories of indicator.
3. A planner browses the plan provided by the system in a graphical way (see Figure 4), and confirms excess and deficiency in the collection activity required to use the indicators.
4. If necessary, planner will return to step 2, and modifies indicator selections.
5. Once all indicators to be used were decided, project process with quantitative management plan is produced.

In the following, we explain two major features of EPDG+.

Indicator recommendation and employment:
This feature provides organizational standard indicators with rating information based on various criteria. Ratings helps novice planners, i.e. inexperienced project managers, select indicators for their own project. As an example, we consider rating based on records of indicator employment in the past projects with similar profile.

Project profile here means a set of characteristic properties of projects such as product size, budget size, business area, planner's experiences (number of projects or years) and etc. Moreover, as another approach, it would be also considered that rating based on process models and standards, for example capability maturity level of CMMI which the organization is aiming.

Process browsing (confirmation of measurement and analysis activity plans embedded):
In order to confirm measurement and analysis activities in the process while planning, this feature enables to browse planned processes with integrated measurement and analysis activities. With this feature, we can confirm whether there are any excess and deficiency between employed indicators and planned measurement and analysis activities which is required by the indicator.

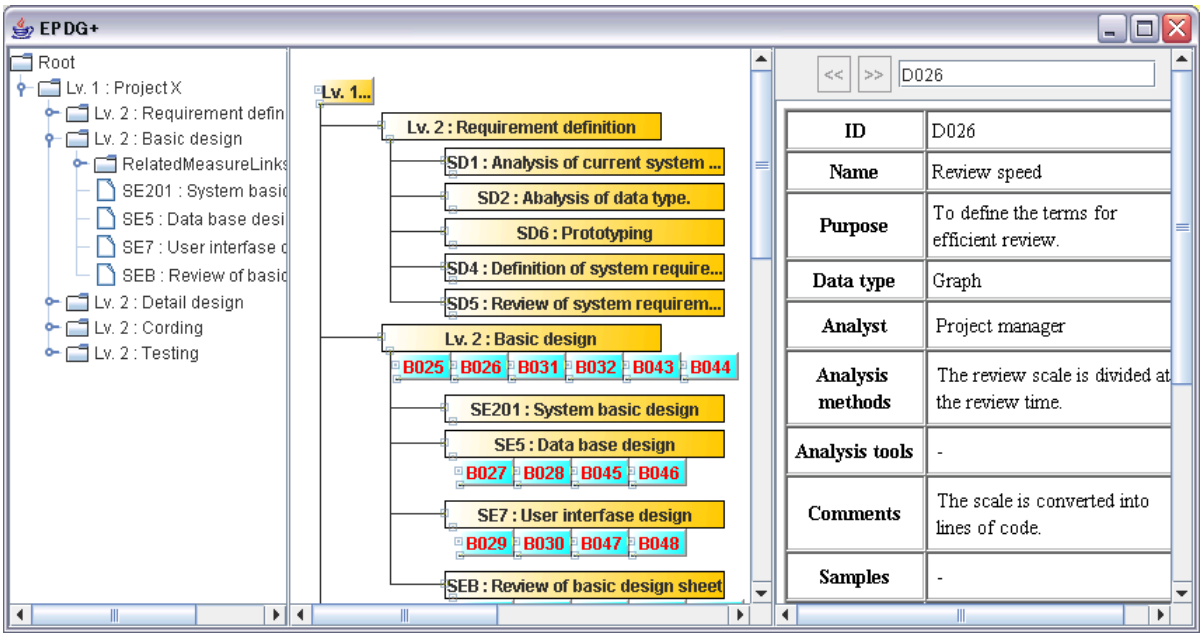


Figure 4 A Screenshot of the EPDG+ prototype for WBS-style process descriptions.

Generally, an indicator is related to one or more development activities, thus a planner has to confirm plural measurement activities for an indicator. This feature therefore makes confirmation task easy by displaying base measure required for each indicator and measurement activities for them side by side.

5.2 Prototyping of the EPDG+ system

EPDG+ aims to support the planner to develop a process description with quantitative management plan by integrating use of selected indicators and associated measurement/analysis tasks into process description, in the early stage of a software development project. In this section, we introduce the prototype of the system. The execution screen image of the system is shown in Figure 4. This system consists of three panes. We explain each pane from the left of Figure 4.

Process summary pane (left): A whole process according to its layered structure such as WBS (Work Breakdown Structure) is displayed to navigate user's process browsing. Although the system currently supports only WBS-style process descriptions, other process model which will have other expressive form, such as PReP (Product Relationship Process) model[7], will be supported in the future. In Figure 4, the system has loaded the whole process description, which consists of phases from requirement definition through testing, is displayed in this pane.

Process investigation pane (middle): The system displays side by side development activities according to process description, and the marks symbolic of measurement associated with each development activity. The user can zoom-in the display range of development activities to this pane by specifying at the process summary pane.
By selecting the symbolic marks in this pane, detailed information of the selected measurement is shown in the indicator exposition (right) pane. In this example, detail of requirement definition phase and basic design phase are shown.

Indicator exposition pane (right): The detailed information, such as measuring method, analysis method, person in charge, and etc. is displayed here. This feature is actually inherited from our original EPDG system[6] that provides fundamental information for process data definition and usage. The detailed information can also be directly searched using searching dialog box. In the example, the indicator of "Review speed" is selected, and the user can refers to its purpose, analysis methods, and etc. More information such as sample of measure data, other related measurements, and etc. is provided as hyperlinks in the descriptions.

The EPDG+ prototype is written in Java, and loads data XML files which describe indicator definitions and process definitions. Implementation of core functions for process browsing and measurement data inspection

has already completed. Features for indicator recommendation by ranking or categorizing are currently under development.

6. Conclusion

In this paper, we remarked that planning quantitative management of the software development process is a difficult task even though the organizational standards of development process and indicators are preliminary provided. This task is very hard especially to inexperienced managers.

In order to discuss potential requirements to assistance method of quantitative management indicator incorporation, we conducted a survey of organizational indicator use in an organization of Japanese industry. We observed that experienced managers often select/modify the indicators to fit the project profile better than inexperienced ones. According to the discussion, we confirmed that systematic support to indicator selection/modification will greatly help to efficient project management.

We also presented the EPDG+ system to support novice managers plan quantitative management tasks to be embedded in the project-defined software process. EPDG+ provides features to browse the project process, to specify employed indicators associated with measurement tasks, and detail of definition and usage of measurement data. Development of the EPDG+ system still continues, and many advanced features for integrated project tailoring support are planned.

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