Industry Paper

Quantitative Process Improvement for Progress Management Process

†Akihiro Hayashi

†Department of Information Design, Shizuoka Institute of Science and Technology, Japan
pixysbrain@gmail.com

Abstract - The concept of process improvement in system development is applied to prevent rework in downstream processes by correctly defining requirements and communication in upstream processes. Although rework related to the entire project life cycle has been discussed thus far, it is necessary to improve each process individually. In this study, we focused on the progress management process, which is most frequently used in the development life cycle. First, we defined the workload as the basis of progress management. We also estimated the project workload in different ways during the project planning stage. The workload delay of the project can be controlled by introducing an earned value management approach to project progress management. The necessary corrective actions were taken. Upon completion of the project, we aimed to improve the estimation accuracy by accumulating workload data as an organization. When this proposed method was applied to a company that achieved Capability Maturity Model IntegrationCMMI level 3, an actual improvement in the accuracy of workload estimation was confirmed.

Keywords: Process Improvement, Progress Management, EVM

1 INTRODUCTION

Process improvement in system development has been widely discussed since the release of the software Capability Maturity Model (CMM) Ver1.1 in 1993. The main idea was to accurately define the requirements in the upstream process and accurately estimate the scale and construction period of the project, thereby eliminating any delays in the downstream process. As a basis for this, a graph was presented showing that if modification occurred in the coding stage of the project life cycle, the modification cost would be less than half in the upstream process; however, if modification occurred in the downstream process, it would increase exponentially. It is important to manage the upstream processes to prevent this type of retrogression.

In this study, focusing on the most frequently used progress management process in system development, we propose process improvement. Progress management is the process of measuring the progress of a project according to the project plan and correcting any discrepancies. The progress management process is basically implemented at the progress meetings. Progress meetings are held weekly in many companies. In some industries, it is common to hold progress meetings every morning. Thus, we can expect to enhance the process through the improvement of the productivity of the progress management process by reducing rework, as well as the time and effort required for progress meetings.

First, we review Capability Maturity Model Integration (CMMI)'s progress management practices and highlight the deficiencies in managing progress. Thereafter, using effort as the basis, we propose a method for estimating the effort of the project, evaluating the progress of the project, and estimating the cost overruns upon project completion. We aim to spiral up by registering the knowledge acquired after the project is completed in the organization's process assets and reflect it in the estimate of the next project plan.

In a prior study in the process improvement field, Mayra Proano-Narvaez et al . [1] evaluated the effectiveness of project management using Earned Value Management (EVM) using the case of a construction company in Cuenca . They reported that EVM plays an essential role in the integrated management of projects in terms of scope, time, and cost. However, this study was not a system development project and did not discuss quantitative progress management. Guoping Rong et al. [2] pointed out that CMMI, which has been validated in the traditional software industry paradigm, has not been evaluated in a DevOps environment. Therefore, we evaluated the application of process improvement using SCAMPI C in an actual DevOps case. As a result, we report that SCAMPI C can be introduced to process improvements in DevOps. Rojrattanakorn et al. [5] pointed out that despite the importance of risk management in software development projects, it is still judged subjectively. In their study, they proposed a method to identify risks using risk taxonomy ontology and CMMI's project planning guidelines. The study reported that this method was effective for the risk management of software projects.

Furthermore, prior research on process improvement and progress management has been reported([3][4][6]), but no research reports how to manage progress consistently from project planning to project completion.

In Section 2, we outline the CMMI progress management process, pointing out the lack of progress management practices and problems to be solved. In Section 3, we propose a method of project progress management for master schedule and work breakdown structure (WBS), and a method of progress management based on man-hours by EVM. Section 4 discusses the results of the application of this proposal to actual projects. In Section 5, we discuss the results, and the conclusions are presented in Section 6.

2 PRACTICE AND ISSUES REQUIRED FOR PROGRESS MANAGEMENT

2.1 CMMI Progress Management Process and Management Items

In CMMI, the most standard process management model currently being used, the equivalent of progress management is project monitoring and control, as shown in Fig.1. This process describes the following goals and practices:

Here, SG1 (goal 1) lists the management items for each progress meeting, and SG2 (goal 2) lists the management items for issues and corrective actions. In other words, SG1 is described as ”weekly management items” and SG2 is described as ”weeks-long management items.” In other words, the progress management practices described in CMMI are intended for progress meetings, which are the main areas of progress management.

2.2 Issues to Be Solved

Notably, CMMI and other so-called best practices describe what to do but not how to do it. Organizations that achieve CMMI level 3 may have successfully introduced the progress management process at that point, but it is debatable whether this specifically improves the progress management process. Adopting a best practice model to implement progress management has not yet been able to establish a methodology that contributes to the overall productivity of the project, and it remains a challenge to be solved.

2.3 Identify Deficiencies in The Progress Management Process

In this study, we conducted a case analysis of progress management in the organizations wherein the author worked. Below is an outline of each organization’s efforts.

A: NTT ’s affiliates are developing prototypes of basic research. They are working to improve the process by introducing the CMMI software as soon as possible in Japan.

SG 1 Monitor the Project Against the Plan
SP 1.1 Monitor Project Planning Parameters
SP 1.2 Monitor Commitments
SP 1.3 Monitor Project Risks
SP 1.4 Monitor Data Management
SP 1.5 Monitor Stakeholder Involvement
SP 1.6 Conduct Progress Reviews
SP 1.7 Conduct Milestone Reviews
SG 2 Manage Corrective Action to Closure
SP 2.1 Analyze Issues
SP 2.2 Take Corrective Action
SP 2.3 Manage Corrective Actions

Figure 1: Project monitor and control

B: As a foreign computer manufacturer, we are strong in large-scale development. We have a unique software development lifecycle and implement project management using global standards.

C: A company that manufactures precision equipment for automobiles; we are proceeding with the improvement of internal processes while sticking to standards and mechanisms, such as CMMI and ISO9001, according to the management’s preferences.

D: An IT development company of a major steel manufacturer; we are implementing in-house process improvements using ISO/IEC 15504. We recommend strict procedures for system development.

Based on the experience with these four organizations and documents such as shared consultation materials and session minutes left in the cloud environment, a fishbone diagram, as shown in Fig.2, was created to identify the factors lacking in the progress management process.

Fishbone diagrams can be used in two ways: organizing and reviewing. Here, the fishbone diagram was used for the purpose of organization. When there are too many factors, each factor is systematically organized by dividing it into common elements and levels of abstraction. In this study, four factors involved in this research were identified by creating a fishbone diagram.

According to the results, four main factors make the progress management process incomplete.

1. Absence of project baselines (Factor 1)
   No key measures have been defined for overall project progress management, and there is a lack of project baselines to serve as milestones for the creation of deliverables.

2. Feasibility has not been assessed (Factor 2)
   The feasibility of creating a correct master schedule and WBS and completing the project on time from a man-hour perspective has not been evaluated based on the evaluation of both top-down and bottom-up.

3. Lack of skills related to WBS (Factor 3)
   WBS does not function as a baseline, even though WBS is being created, the WBS code is not defined correctly, and the WBS dictionary is formally written with the start and end dates.

4. Lack of cost progress measures (Factor 4)
   In the development phase, reliable costs have not been calculated and are being calculated. To meet deadlines, costs are secondary, while cost consciousness is low.

3 QUANTITATIVE PROCESS IMPROVEMENT FOR PROGRESS MANAGEMENT PROCESS

In Section 3, to solve the problems presented in Section 2, we propose a method for continuous improvement of the progress management process. We present the basic policy of this study and comprehensively explain the proposed method.

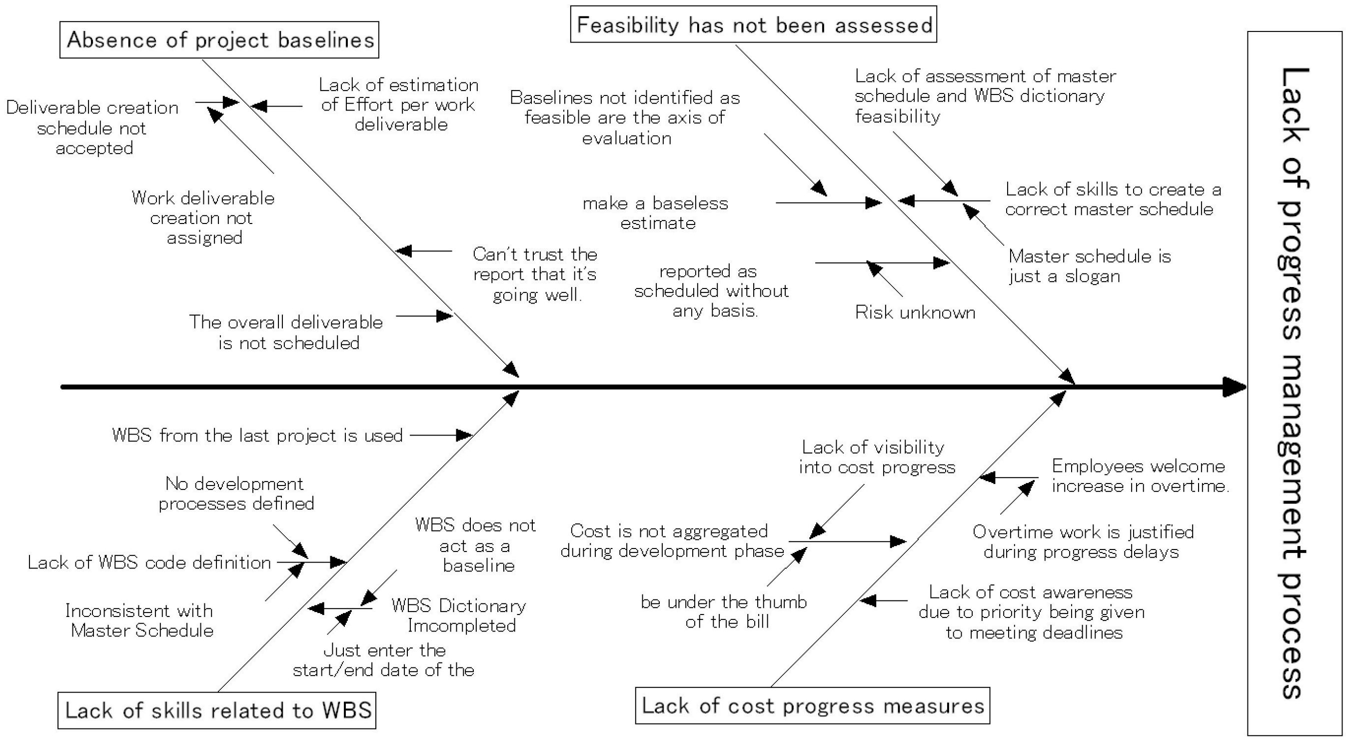

Figure 2: Insufficient factor of progress management

3.1 Basic Policy

The key to successful project management is creating a feasible project plan, operating the project in accordance with the plan, and adapting to the changes and risks that occur in the middle of the project. In this study, effort was considered the key parameter and basis of progress management.

At the project planning stage, the effort and construction period of the new system are estimated using several methods, and the master schedule and WBS are created using the effort as the axis. Thereafter, progress reports and risk assessments are made using EVM based on the effort. Upon completion of the project, the relationship between the characteristics of the project and effort is registered in the organization's process assets and utilized in the next project, aiming to spiral up progress management based on effort. This method solves for the four factors shown in the fishBone diagram. This situation is illustrated in Fig. 3.

3.2 Project Planning

3.2.1 Effort and Period Estimation

We define the requirements in the most detailed way possible to start a project and use the source lines of code (SLOC) as the scale of the new system. In this study, we do not discuss the method of scale estimation using SLOC; we use top-down and bottom-up approaches to estimate the effort.

Table 1: Effort Estimation Adjustment

Top Down Approach	Conversion to Effort using the CoBRA method
Bottom Up Approach	Calculation of Effort by stacking WBS

The top-down approach refers to the CoBRA method that converts SLOCs into effort. CoBRA is an estimation method that visualizes a "guess." For example, it quantifies user experience values, such as user communication, level of performance requirements, ambiguity of requirements, and system complexity as risks of system development. The effectiveness of the CoBRA method has been confirmed in many previous studies [7][8].

The bottom-up approach to man-hour estimation refers to the accumulation of man-hours required to create work deliverables described in the WBS.

The bottom-up approach to effort estimation refers to accumulation of the effort required to create work deliverables described in the WBS. For an organization that introduces CMMI, a configuration management plan is prepared at the time of project planning, and the work output (including source code) and number created for each process are identified and assigned to the person in charge. If a person takes five days to produce a work deliverable, it takes 50 days to produce ten work deliverables. By accumulating the effort created for each process, the overall effort of the project is determined from the bottom up.

The effort obtained by the top-down approach is the overall effort of the project. There is no perspective on when, who, what, or how to work. The effort obtained by the bottom-up approach is cumulative; concurrent tasks are not considered, and estimates are calculated from the values obtained from the top-down and bottom-up approaches to calculate the ap-

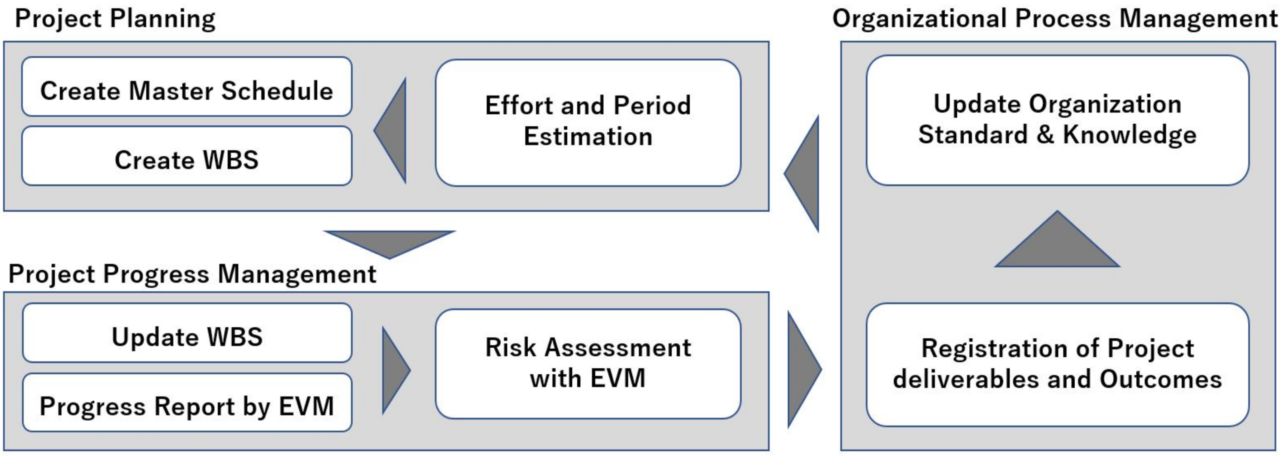

Figure 3: Relationship between project plan, progress management, organization process asset

proximate effort of the project, as presented in Table 1.

3.2.2 Master Schedule Creation

Next, a comprehensive view of the entire project master schedule is created. The master schedule is a sheet of paper that lists all the processes, milestones, and major events from start to finish of the project: Program Evaluation and Review Technique (PERT) projection.

Once the master schedule is completed, the critical path refers to a path that cannot be accelerated owing to the dependency on the processes and tasks. By applying the organization's development phase to the critical path and visualizing the start, inter-process dependency, and minimum lead time, reliable process management becomes possible.

In the master schedule, the development process is described up to the WBS code, with another stage breakdown, and the required time is expressed as the length of the horizontal line of the PERT. In this study, we used the three-point estimation method, which is used in management and information systems applications for construction. In the three-point estimation, three parameters were used based on prior experience or best-guesses :

$$a = \text{the best - case estimate}$$
$$m = \text{the most likely estimate}$$
$$b = \text{the worst - case estimate}$$

These values are calculated as the E value that considers both the most optimistic and most pessimistic estimates provided.

$$E = (a + 4m + b) / 6$$

3.2.3 WBS Creation

Once the master schedule is created, the effort for the entire project and the start and end dates are fixed, and how long it takes for each development period is known. The WBS is created, as shown in Table 2. The left side of Table 2 is "WBS," which is the top-level content consistent with the master schedule. The "WBS Dictionary" on the right side of Table 2 refers to the person in charge, the necessary man-hours, the start date, and the end date, and the specific tasks used for progress management.

It is difficult to detail the WBS at the project planning stage; therefore, the project planning is equivalent to the master schedule. However, when the project starts, each development phase breaks down into manageable tasks. A manageable task is to break down a person's task into no longer than five days, start–end date, and effort.

3.3 Project Progress Management

3.3.1 WBS Update

The project progress management process was conducted in progress meetings held by the project bodies. In many projects, progress meetings are held once a week and the WBS is updated accordingly.

In updating the EVM, the cost accounting standard for activities will be "50%-50% rule." When the work begins, 50% of the estimated man-hours will be recorded as progress. After that, the remaining 50% will be recorded upon completion, not until completion. The EVM's accounting methods include "0%-100% rule," "20%-80% rule," and so on. In this study, simplicity is prioritized over strictness because progress management is held once a week and activities are within five people's days; therefore, even if progress is delayed, most of them are expected to be caught up the following week.

By updating the EVM, the parameters at that time are obtained. Figure 4 shows the EVM concept and the parameters used in progress management. This graph shows the costs along the vertical axis and time on the horizontal axis. In the planned value (PV) of this graph, the proficiency curve (S-curve) is the cost baseline. This is the planned cost of an activity based on the schedule.

The EVM basically understands PV, EV, and AC at the project site, and other values can be calculated; therefore, the other parameters are calculated by the formula built into the WBS form. The results are presented in Table 3.

3.3.2 Progress Report by EVM

In previous progress meetings, there were many subjective and ambiguous reports. This study eliminates this ambiguity

Table 2: WBS and WBS Dictionary

WBS			WBS Dictionary					
Phase Name	WBS Code	Work Package	Author	Estimated Start Date	Estimated End Date	Estimated NOS Items	Average Effort	Estimated Effort
Design Phase	Screen Design	State transition diagram	AAA	MM/DD	MM/DD	10 items	2 Days	20 Days
...	...	...	...	...	...	...	...	...

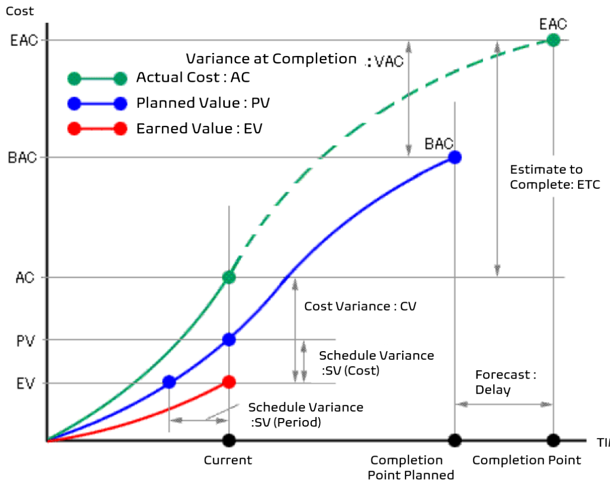

Figure 4: Concept of EVM

Table 3: EVM Terms and Calculation

Abbrev	Translation	Calc
BAC	Budget at Completion	
PV	Planned Value	
EV	Earned Value	
AC	Actual Cost	
SV	Schedule Variance	EV-PV
CV	Cost Variance	EV-AC
SPI	Schedule Per Index	EV/PV
CPI	Cost Per Index	EV/AC
ETC	Estimate to Completion	(BAC-EV)/CPI
EAC	Estimate at Completion	AC+ETC
VAC	Variance at Completion	BAC-EAC

and provides objective reports using EVM values, as shown in Table 4, which describes the progress measure.

This study regards man hours as the cornerstone of project progress management. It predicts future man-hours excesses, always conscious of the cost difference between completion and variance at completion (VAC). The EVM volume is equivalent to the cost. Project progress management uses ”man-day” frequently, so costs can be regarded as ”man-day.” It has been reported that the expression ”SV is -five man-days.”

3.3.3 Risk Assessment with EVM

After receiving the report from each person in charge, we conducted progress analysis and risk assessment using the parameters of the EVM. The standard values for the progress analysis are presented in Table 5.

In the progress analysis, if the SPI or CPI reported exceeds the ”standard value” in Table 5, it is noted as ”smokey.” If the delay continues for more than 3 weeks, or if the delay increases, it will be judged as ”fire-extinguishing” and ”fire-extinguishing team” will be introduced.

In the risk assessment, a time series analysis of SPI and CPI is performed, as described in Fig.5. A graph is created with CPI along the vertical axis and SPI on the horizontal axis, and each delay is visually identified as accelerating or stopping falling. If CPI decreases at the same time as SPI, development productivity (SPIxCPI) will decrease and man-hours will significantly exceed expectations. Alternatively, if you know that you are sacrificing CV to maintain SV from a certain point in time, you can estimate that you are compen-

Table 4: Measure of Progress

ECM Express	Changes
SV is -5 days	Report SV values instead of reports like “one week delay”
ETC is 50 man-days	ETC is reported to understand “So What”
SPI is lower than 0.9	Quantitatively reports the delay, not the “slightly late” report
VAC is 50 man-days	VAC is reported as a quantitative value of delay

Table 5: Measure of Progress

Measure	Criteria	Description
SPI	<0.9	Schedule progress delayed by 10%
CPI	<0.9	Cost Progress delayed by 10%
SPI*CPI	<0.8	Development Productivity delayed by 20%
EAC/BAC	>1.1	10% cost over when completed

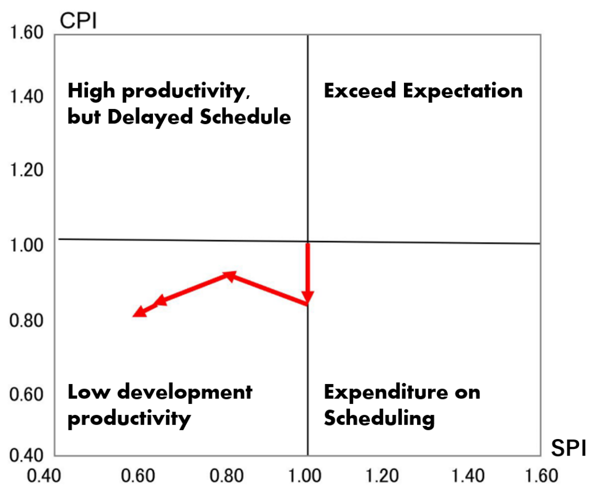

Figure 5: SPI/CPI Time Series Analysis Example

sating for it by working overtime or taking time off if you do not include additional factors.

Finally, we use EAC/BAC to determine the overall status of the project; if the EAC/VAC value exceeds the threshold (e.g., 110%), it means 10% or more of the cost overruns of the plan at the end of the project. These escalate to senior management, who make decisions such as acceptable project cost deficits and push customers for extra staff to ensure quality.

3.4 Organization Process Management

3.4.1 Registration of Project Deliverables and Outcomes

After completing the project, all work products and process assets of the project will be registered in the organizational process asset database.

Generally, the means to increase productivity include increasing the mechanization rate, concurrency, utilization rate, and reuse rate. In the case of manufacturing, such as in system development projects, improvements in reuse will greatly contribute to productivity improvement.

In addition, activities, such as project management, can inevitably lead to trial and error. By reusing the process assets of successful projects, one can expect to save trial and error effort.

Organizations that use CMMI plan the work output for each development phase of the configuration management plan. Keep a record of the work output consistent with this plan. In principle, all the work output of a project should be registered in the organization process asset database and reused in the next project.

3.4.2 Organization Standard and Knowledge Update

In the proposed method, decisions are made in the following parts of the project using intuition and subjective judgments.

- In estimating man-hours, we combine the top-down approach and the bottom-up approach to make estimates. At this time, we do not simply take intermediate values, but make decisions based on the knowledge of experienced people.
- Using the CoBRA method, we use parameters that express the knowledge of experienced people as quantitative values.
- In the PERT projection of the master schedule, pessimistic and optimistic values are calculated using rules of thumb when defining the period of the development phase.
- Progress analysis was conducted using EVM values at the progress meeting, and thresholds for values such as SPI/SPI, VAC/EAC were determined.
- Based on the project period, we use a rule of thumb to determine how long the delay can be recovered.

Once the project is completed, we will verify whether such a subjective judgment is correct and include it in the process asset database as a lesson learned. These lessons are not something that can be used as is, so we aim for a spiral-up by turning this cycle many times.

If you do not have the experience, it is not good to think that you can ask about the experience even if you are in the same organization . Since the rules of personal experience are tacit knowledge, implicit knowledge is likely to be lost owing to retirement or other reasons. You must quickly formalize it and incorporate it into organizational knowledge.

4 APPLICATION RESULT

The results of the application of the proposed method at Company C, which appeared in the case analysis in Section 2, are explained herein.

As explained in Section 2.3, Company C is the company in which the author worked. The author was conducting in-house consultations at Company C for CMMI level acquisition. Until the author joined the company, progress was managed ambiguously. The author proposed the introduction of this method and implemented it over a period of approximately three years.

Company C is developing embedded software for measuring the instruments. Derivatives such as enhancements are

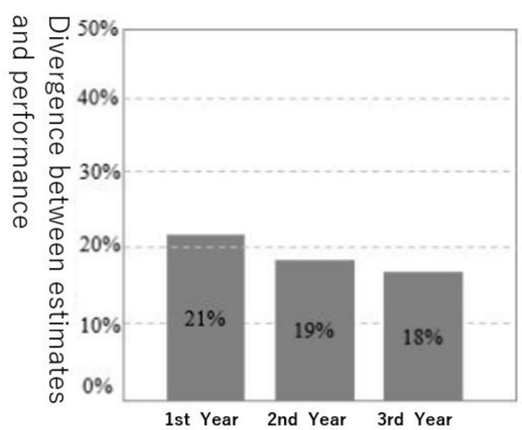

Figure 6: Changes in VAC Ratio to Total Effort

often used in manufacturing measuring instruments. It is difficult to apply the function point (FP) method for the development of embedded systems with precision instruments.

When the company applied this proposal method, SLOC estimated the scale of modification of the previous derivative development of the same model and the area to be modified. Next, considering the frequency of customer demand changes, difficulty of neck technology, and frequency of interface changes, the CoBRA method was used for conversion into man-hours.

Next, we created a WBS for this development by reusing the WBS from the previous derivative development project and estimated man-hours by accumulating the described man-hours. Finally, we calculated the man-hours for this project by combining the two.

After completion of the project, the accuracy of the estimates was measured using the VAC value. The following graph shows the change in the estimation error for approximately three years after the introduction of the proposed method.

In the first year, the difference between the estimates and VAC performance was more than 20%. Three years ago, it had improved by 3%, as shown in Fig.6. This company has adopted only this proposed method, so the improvement effect can be attributed to the proposed method.

5 DISCUSSION

Here, we examine the evaluation of the problem solving described in Section 2.3, and the effects of other process improvements.

5.1 Evaluation of Problem Resolution

5.1.1 Absence of Project Baselines

In this study, as part of project progress management, we proposed a method that takes man-hours as the basis. We created a project plan based on man-hour estimates and managed progress using WBS and EVM.

We solved the problem of vague and unfounded progress reports, such as "one week behind schedule," which was common in previous progress meetings, and made it possible to use objective and quantitative parameters in progress reports.

5.1.2 Feasibility Has Not Been Assessed

In this proposal, experience in the organization's process assets is used for estimating man-hours in the upstream process, determining progress in the development phase, and risk in process management.

For example, in the upstream process, a realistic estimate is made by combining top-down and bottom-up approaches, and after the project is completed, the certainty of the estimate is verified using VAC. In the next project, we will use this learning for estimation.

In our next project, because we are working on the estimation error of the previous project, the estimation error will be more accurate. The rule of thumb is used to avoid repeating the same failure, and it can be evaluated as a feasible methodology.

5.1.3 Lack of Skills Related to WBS

Organizations repeatedly accept projects with the same difficulty and size. Therefore, once WBS is completed and registered as an organization's process assets, the majority can be reused.

In addition, this study established the "50%-50% rule" as the accounting standard for WBS and established the standard value for interpreting the EVM. Consequently, objective risk assessment that was not dependent on the EVM value was also possible.

Organizations that achieve CMMI level 3 rarely have the opportunity to create WBS from scratch and can use historical data. The lack of skills related to WBS was eliminated by standardizing the start of WBS use, EV accounting, and EVM value interpretation.

5.1.4 Lack of Cost Progress Measures

In EVM, whether the cost should be the amount or time is debatable. In this study, we used man-days as the cost of EVM and used it as a consistent progress scale from upstream processes. By using cost as man-days, progress scales such as SPI and CPI can be quantitatively evaluated.

5.2 Impact of Process Improvement

5.2.1 Progress Reports Ambiguity Elimination

In the project subject to this application evaluation, EVM was consistently used in the progress report. Now the report format is "-10 man days for PV" instead of "delayed by about a week."

Company C conducted this basic operation throughout the project period, and there was no confusion when using this method. EVM is supposed to measure the cost in hours or money, but this method is basically the same because the cost is recorded in man-days.

In the previous method of reporting, "delayed by about a week," it was unclear whether that week was a week on the calendar week of work (i.e., a five-person day), but as we were unable to report "one week" after this proposal, it was evident that the delay was a five- or seven-person day.

By implementing the basic action at the progress meetings, the things that no one had noticed, even if they were left ambiguous, were replaced by quantitative expressions. This is also considered an improvement.

5.2.2 How to Grasp the Time of the Progress Meeting

At Company C, the progress meeting was held once a week from 10 a.m. to 12 a.m. on Fridays, and the company worked eight hours a day five days a week; thus, two hours out of 40 hours a week, excluding overtime, were held in progress meetings.

Generally, the time spent on system development is classified into three categories: manufacturing, regular meetings, and management. It is said that approximately 15-20% of the time spent on management is appropriate.

Until the introduction of the proposed method, Company C regarded the time of the progress meeting as a regular meeting, but after the introduction of the proposed method, it was able to grasp the progress of WBS tasks, quantify the progress of the entire project, and calculate future risks.

Whether to have a regular meeting or management time is decided subjectively to some extent when the person in charge records the time, so it is difficult to evaluate the increase or decrease in specific numbers.

However, since the introduction of this proposal method, stakeholders who participated in progress meetings have come to view progress meetings as a place for project progress, so the time taken for regular meetings has decreased, and time for inevitable management has increased.

6 CONCLUSION

This study focused on individual process improvement, such as ”progress management.” The so-called best practices, like CMMI, just include what to do, but do not provide enough description of how to do it.

Therefore, we proposed man-hour-based practices, such as estimating man-hours at the project planning stage, meeting progress at the process management stage, and registering process assets after the project is completed.

By using this method, we eliminate subjective and ambiguous progress reports, such as ”delayed but good,” that were used at previous progress meetings, and are able to quantify the risk assessment using EVMs, so we can see how much cost will be overrun at the end of the project.

However, this study did not evaluate the EVM threshold. For example, the SPI/CPI threshold started at 0.9, because companies such as IBM and Unisys set the threshold at 0.9. However, the pros and cons of small and medium-sized enterprises imitating the practices of large enterprises, such as IBM, have been repeatedly discussed, and if $SPI < 0.9$, the risk of becoming obsolete is indicated.

It is reasonable to spiral up by accumulating the lessons learned. Establishing correct thresholds for each development site will be a challenge in the future.

REFERENCES

[1] M. Proano-Narvaez, et al, “Earned Value Method (EVM) for Construction Projects: Current Application and Future Projections,” Buildings, Vol. 12, No. 3, 301(2022).

[2] G. Rong, et al, “CMMI Guided Process Improvement for DevOps Projects: An Exploratory Case Study,” 2016 IEEE/ACM International Conference on Software and System Processes (ICSSP), pp. 76-85, (2016).

[3] S. Chunli et al, “Research on Software Project Quality Management Based on CMMI,” 2016 International Conference on Robots and Intelligent System (ICRIS), pp. 381-383, (2016).

[4] M. Choetkiertikul, et al, “A CMMI-Based Automated Risk Assessment Framework,” 2014 21st Asia-Pacific Software Engineering Conference, pp. 63-68, (2014).

[5] C. Rojrattanakorn et al, “Automated Risk Identification of CMMI Project Planning Using Ontology,” 2017 5th Intl Conf on Applied Computing and Information Technology/4th Intl Conf on Computational Science Intelligence and Applied Informatics 2nd Intl Conf on Big Data, Cloud Computing, Data Science (ACIT-CSII-BCD), pp. 19-24, (2017).

[6] A. Odeh, et al, “A Model for Understanding Project Requirements based on CMMI Specifications,” 2021 International Conference on Engineering and Emerging Technologies (ICEET), pp. 1-6, (2021).

[7] Introduction to CoBRA method, CoBRA Laboratories, Ohmsha, (2011).

[8] Y. Mizukami, et al, “Improvement of Workload Estimates by using project characteristic based on CoBRA Method for Software Development Project,” Journal of Japan Society of Directories, Vol 11, pp. 36-45, (2013).

(Received: September 24, 2021)
(Accepted: August 23, 2022)

Akihiro Hayashi received his MBA and Ph.D. from the University of Tsukuba, Tokyo, Japan in 1997 and 2010, and his Ph.D. in Software Engineering from Nanzan University, Nagoya, Japan in 2019. His professional career includes global companies such as Motorola USA, NTT, and IBM Japan. In 2018 he has become a Professor of Department of Information Design, Faculty of Informatics, Shizuoka Institute of Science and Technology. His current research interests include process improvement, quantitative project management, operating research and management strategy. He is a member of IEICE and INFSOC.