Historical Significance and Suggestions on Future Works of Software process Improvement in Japan

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Abstract. Various types of software process improvement activities have been carried out in each company to achieve good results in Japan. The process improvement activities and methods have to be organized from comprehensive perspective for more progress in the future. In this paper, we draw up a chronology of important events related to software development to look back on a history of software process improvement in Japan. Furthermore, the chronology is divided into three periods and we try to find historical significance in each period.

(1) QC/TQC-based improvement phase (1971-1990)
(2) Model-based improvement phase (1991-2006)
(3) Mixture phase of Model-based and Problem-based improvement phase (2007-2015)

According to the investigation, we suggest future works in software process improvement in Japan.

Keywords: QC/TQC, model based improvement, problem based improvement, ISO/IEC 15504, SW-CMM, CMMI, ISO9000-3, SaPID

1 Introduction

Various frameworks, including CMMI and ISO/IEC 15504, have been proposed to evaluate and improve the software process and have been introduced and utilized at many organizations around the world. In Japan, there was an SW-CMM / CMMI boom from the late 1990s to the mid-2000s. After that, there was an anti-CMM movement as a backlash to the boom, and, while some organizations are promoting process improvement based on problems, other organizations are utilizing CMMI and other frameworks to steadily promote process improvement. In addition, in recent years, companies that develop or run game and E-commerce websites, for which the organizational scale is increasing drastically, have started expanding their efforts to include process improvement activities. The Software Process Improvement Conference (SPI Japan Conference), which was held annually in October starting in 2003, has made 30 to 40 presentations and welcomed around 200 participants. Based on this result as

well, it seems clear that a certain number of companies in Japan are aware of software process improvement activities and are implementing them.

However, the fact that there have been few presentations at the SPI Japan conference regarding the achievement of both model conformity and effectiveness makes it possible for us to surmise that not many organizations have implemented effective process improvement activities after adapting various process models.

In Japan, approximately 20 years have passed since process improvement activities started becoming widely recognized and spreading. However, the country has not yet reached the ideal state for process improvement activities, which is to conduct "process improvement activities that achieve both conformity with various models and effectiveness."

This paper examines the causes of not reaching this ideal state based on historical SPI efforts in Japan and then presents a possible direction for dealing with the causes and resolving these issues.

2 Historical characteristics of SPI in Japan

One characteristic of SPI activities in Japan is that an emphasis on quality has conventionally been demanded for software development as well, which has played a part in Japan's manufacturing industry, an industry recognized around the world for putting quality first. In the 1980s, companies with systems called software factories, at which quality is incorporated starting with upstream processes, appeared [5] [6]. Following this, a constant demand for high quality continued due to the strong quality awareness of consumers [7].

The second characteristic is that development methods have changed as the range of products including software has increased, and SPI has also changed accordingly. In particular, in Japan—which is said to be strong in terms of the ability to devise embedded products by integrating ideas—the necessity of SPI has increased as the scale of the software has expanded [8] [9].

The third characteristic is the appearance of ISO 9001 and other certification standard systems as well as CMMI and other assessment / appraisal systems [10]. Japan's involvement in such efforts has hardly been sufficient, and, at least on the on-site, it cannot be denied that the situation was in some way analogous to the attack of Commodore Perry's black ships towards the end of the Edo period. When coupled with the tendency of Japanese people to try to follow rules [11], there was some progress in terms of on-site improvement, while this also involved a lot of burdens that seem unnecessary at a glance. In many cases, oral explanations were not considered acceptable, and evidence was demanded for everything. At the same time, more than a few organizations put themselves in self-contradictory situations in which there were cries for efficiency improvement as well as strict adherence to delivery times in addition to the need to build evidence [12].

3 SPI periods in Japan

In this chapter, the chronology of Japan's SPI is divided into three phases and discussed.

The first period is classified as "Phase 1. The QC/TQC-based improvement phase." As mentioned above, during this period, high quality was demanded of software development as part of the manufacturing industry, and software development organizations incorporated the same sorts of QC/TQC used at manufacturing sites into their own efforts [13] [14]. This period here is decided to be from 1971 to 1990.

The next period is classified as "Phase 2. The model-based improvement phase." The word "model" refers to a software process model. "Model-based" indicates an SPI method that advances improvement of the software process of one's company by comparing it to the corresponding software process model [15] [16]. In other words, the "model-based improvement phase" was a period during which this SPI method gradually entered the limelight, and many organizations incorporated it into their model-based improvement [17] [18] [19]. In this paper, the onset of this period is set to be in 1991. In 1991, the Japanese version of the original paper related to the CMM, the representative process model, was published [20], and there was a major reaction. During the same year, ISO 9000-3 was also issued, ISO 9001 and other quality assurance standards were applied to software development, and people started expecting them to have an effect.

The third period is classified as "Phase 3. The mixture phase of model-based and problem-based improvement phase." The term "problem-based" means that this is an SPI method that involves making improvements mainly by taking up the problems of the corresponding department [21] [22]. The "mixture phase of model-based and problem-based improvement" refers to the period when more organizations incorporated "problem-based improvement" as either a next step after or alternative to "model-based improvement" [23] [24]. In addition, models became more diverse for each product, and there emerged cases of applying it to hardware design in cooperation with functional safety and similar efforts [25] [26]. Here, this period is set to have started in 2007. In 2007, the number of ISO 9001-certified organizations in Japan—which was a core aspect of model-based improvement—decreased for the first time, while IPA/SEC's *Why What* [27] was issued, and the term "problem-based improvement" became widely known.

4 Evaluation of the results of improvement methods for each phase and related considerations

This chapter describes the ways in which the improvement methods for the three phases presented in the previous chapter were evaluated and the evaluation results, followed by the results of consideration based on the evaluation results.

4.1 Evaluation method

The situation and background at any given time have a major effect on the selection of the improvement methods to use, while the improvement-method characteristics have a major effect on the results and achievements of utilizing them. To clarify this chain, we evaluated the main improvement methods for each phase described above as well as the results of these methods, taking the situation and background at the time also into consideration, with respect to the following items:

(1) Improvement method characteristics
(2) Main results achieved

The "main results achieved" are evaluated based on conformity with the capability levels proposed by process models as well as their effectiveness. The capability levels of process models utilized for process improvement mainly express the degree of organizational sharing / utilization and implementation of project management and software engineering. This is indicated on the horizontal axis as "process-model conformity." At the same time, the corresponding results—including the level of results achieved by individuals, teams, and organizations—are indicated on the vertical axis as the "effectiveness," to evaluate the main results of each phase based on where they are positioned on the graph.

Based on the above coordinate axes, the following four states exist, which are shown in figure 1:

(1) Lawless area:
In this state, although there are rare successes, there is constant confusion, and the desired results cannot generally be achieved.

(2) Dependent on individual efforts:
In this state, implementation has been achieved only by specific individuals, so any results depend on them.

(3) Superficial:
In this state, the team or organization is attempting to share and utilize manufacturing and management know-how, but implementation has not been achieved at a fundamental level.

(4) Ideal:
In this state, as manufacturing and management know-how as well as states that enable implementation are shared, utilized, and updated on a team, project, and organization-wide basis, it is possible to continuously increase the feasibility of achieving QCD goals and improving CS.

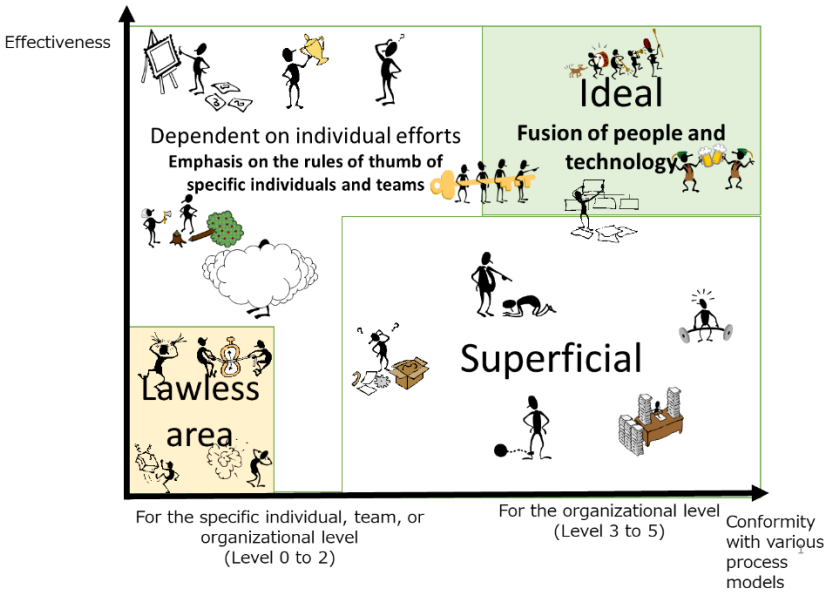

Fig. 1. Process-model conformity and effectiveness evaluation graph

4.2 Evaluation results

In this section, the results of our evaluation based on the method presented in the previous section are presented.

4.2.1 The QC/TQC-based improvement phase

Improvement method characteristics

The advantages of and problems associated with applying QC/TQC to software development at the time include those below.

- Advantages
  - Examples of successful experiences in the manufacturing industry were readily available, so introduction was easy.
  - It was possible to share the big picture of improvement processes, including problem and bug analysis.
  - Methodologies and techniques that included the seven QC tools and QC circle activities were established.

- Problems
  - Management methods that did not consider software characteristics and features were widely used.
  - There was a focus on management methods and few technical approaches.

- Similar to what occurred in the manufacturing industry, activities ended up as nothing more than a mere façade in some cases.

Main results achieved
Representative results achieved during this period include SWQC [13] and AYUMI activities [14]. During this phase, some manufacturers, etc. successfully implemented organizational management (TQC) by imitating manufacturing-industry models such as the above and produced good results, while many other organizations implemented partial or fragmentary QC approaches and activities. It can be surmised that the main results during this phase were achieved in a "state dependent on individual efforts."

4.2.2 The model-based improvement phase

Improvement method characteristics
The advantages of and problems associated with model-based improvement are summarized below.

・Advantages
- The improvement methods were documented, and it was easy to share knowledge on process improvement.
- It was possible to obtain business advantages due to the certification system.
- It was easy to obtain approval for both overseas and domestic introduction as well as certification results.

・Problems
- Evaluations were based more on model conformity than improvement results.
- There was not much of a common understanding regarding improvement objectives, and improvement-method activities tended to focus excessively on the means themselves.
- The improvement culture cultivated using QC/TQC during phase 1 became weaker.

Main results achieved
As a result of the sudden increase in system applications as well as the degree of development-environment freedom, various new development methods, tools, and other choices emerged, and there was a need to utilize process models in order to implement management in line with software characteristics. However, due to this rapid spread, more than a few organizations prioritized "top-down" details, "process definitions," and similar issues as recommended by process models, and they only "set up organizational standards" to avoid the main issue. Although some organizations achieved results through process-model application, it can be surmised that the main results during this phase were achieved in a "superficial

state."

4.2.3 The mixture phase of model-based and problem-based improvement phase

Improvement method characteristics
One major characteristic of phase 3 is that organizations started returning to the QC/TQC problem-solving improvement approach from model-based activities. As the misconception spread that the process had become impersonal due to mistaken model introduction, many organizations shifted to a problem-solving improvement approach in search of results mainly based on the capabilities and wisdom of people. The spread of agile software development to Japanese sites was also due largely to an approach that emphasized engineers as opposed to the fundamental goals.

Phase 3 was a period during which each organization reflected on phase 2 (the model-based improvement phase) and considered its experiences during phase 1 in order to establish improvement methods in line with the organizational culture of its departments.

Main results achieved
It can be surmised that the main results achieved during this phase were a combination of the results achieved during phases 1 and 2.

4.3 Considerations

As a result of our historical evaluation of SPI activities in Japan, the three common problems below became apparent. In this section, we explain these three problems.

4.3.1 The problem of choosing between two alternatives

The problem of choosing between two alternatives refers to choosing only one of two choices and then simultaneously failing to satisfy both.

During all the phases, it appears that specific items were emphasized and activities were conducted to achieve them. For example, during phase 1, most improvement activities were conducted in a bottom-up style by individuals and teams involved in work. During phase 2, there was a shift to top-down improvement activities aimed at achieving comprehensive progress under the control of the organization. Finally, during phase 3, activities were divided between those that were bottom-up and those that were top-down.

In addition, issue and problem-based improvement activities were conducted during phase 1, process-evaluation-based improvement was pursued during phase 2, and efforts were divided between issue and problem-based improvement activities and process-evaluation-based improvement during phase 3.

The goal to be achieved primarily is to fuse two aspects that seem contradictory at a glance in order to achieve both simultaneously. However, based on what has happened until now, it seems as though activities have oscillated between emphasized

items that are complete opposites during all the phases. Table 1 shows typical pairs of such alternatives.

Table 1. Typical pairs of alternatives

Top-down	⇔	Bottom-up
Following internal norms, in-house activities	⇔	Following external norms, external certification
Organizations	⇔	Individuals
Model-based	⇔	Issue and problem-based
Control, tightening	⇔	Leaving things alone, freedom and autonomy
Technology	⇔	People
Conformity, formalization	⇔	Goal achievement, flexibility
Quality	⇔	Costs, periods

4.3.2 Activities becoming a mere façade (means becoming ends)

Something becoming a mere façade refers to a state of losing its initial meaning and being ended up as nothing but a hollow shell of what it used to be.

Problem-based improvement activities have the potential risk of becoming a mere façade that improvements are not made unless clear issues and problems are recognized such as post-delivery failures, suggestions from customers, commands issued by superiors.

Meanwhile, because model-based improvement is based on conformity assessment systems and external assessment results, there is a tendency for organizations to align their activities with process models to pass assessments or reach certain levels. In addition, it can be said that the fact that the assessment of model-based improvement based on the ISO 9001 certification system and SW-CMM rapidly spread starting in the mid-1990s partly helped increase the tendency of the associated activities to become a mere façade.

4.3.3 Loss of a sense of purpose and goal switching

It seems that weak, ambiguous improvement goals as well as a failure to follow through are common problems that could be major factors in terms of causing the problem of choosing between two alternatives as well as activities becoming a mere façade.

As a result, it is assumed that there has been a tendency to switch to easily understood goals related to the means as opposed to the ends, including “conformity / certification,” “reaching certain levels,” and “applying these.”

It can also be argued that in the background of the ISO 9001 conformity assessment system and SW-CMM assessment rapidly spreading during phase 2 was making “jumping on the bandwagon” the end in and of itself due in part to the Japan’s distinctive “lockstep mentality.”

Such loss of a sense of purpose generates the problem of choosing between two alternatives, and activities becoming a mere façade, which led to organizations that failed to achieve any actual effects reverting to past activities or wandering in search of other methods and approaches. In addition, there were repeated cases of organizations jumping at new methods and approaches whenever they became popular.

5 Proposal on future SPI

In this chapter, a direction for the future of SPI in Japan (phase 4) is proposed based on the history of SPI in this country as explained in this paper.

5.1 Fusing organizational approaches and technology

One perspective required of future SPI in Japan is to promote process improvement based on the perspectives of both organizational approaches and technology. This is also a solution to the problem of choosing between two alternatives, which was described in the previous chapter. The essence of this problem lies in the selection of only one of two conflicting events. During phase 4, it will be necessary to fuse organizational approaches and the technological perspective in terms of methods suitable for organizational goals, organizational cultures, current levels, developed products, etc. based on Japan's SPI-related experience and reflection up until now. This will ultimately result in the pragmatic selection of the left and right items in Fig. 1, leading to a perspective that makes it possible to create new improvement methods.

In reality, based on the evaluation results in 4.2, it is necessary to solve the problems associated with improvement methods that have been selected by organizations. Until now, SPI has been promoted mainly as a way to improve the development process, but it will also be important to simultaneously improve the process improvement methods themselves. For example, for sites where there is an emphasis on the experience of specific individuals or teams, understanding process models is effective. In addition, for organizations where model-based improvement methods are top-down and have become superficial, the bottom-up improvement perspective can likely serve as a reference.

5.2 Introducing technology focused on people and a practical approach

In terms of implementing the proposal in 5.1, the things that have been missing in terms of the scientific perspective of Japan's development organizations are the insights of people and organizational activities based on them. Although there have been many results until now in terms of research related to software development technology and processes, there is still room for improvement regarding technology focused on people and a practical approach. Japan's software development organizations are often brought up due to mental problems, and this is evidence of development organizations not paying enough attention to people. Considering the fact that

software development products are created by engineers as opposed to machines, scientific management methods based on psychology and human relations should be the subject of more focus. Engineers are human resources, and it is difficult to secure quality or productivity without investing in them. This is a difference compared to the manufacturing industry and is a typical software development characteristic that is not shared with other types of industries.

Compared to Japan, the USA has more theories concerning people and organizations, including knowledge on human relations based on the Hawthorne experiments compiled by Mayo. In Japan, there is, in reality, a prevalent belief that where there's a will, there's a way. If Japan does not learn from the theories of Europe and America in order to come up with an approach for both people and organizations that is suitable for Japanese organizations, engineers will continue to become exhausted, and there is a risk of this preventing development from continuing. Investing in people surely has a proportional result in terms of what is achieved. Regarding technology focused on people and implementation for software development, machines are maintained in the manufacturing industry, but maintaining people is many times more difficult than maintaining machines. However, we must not forget that investing in people can result in up to 10 times more productivity [28] and up to a hundred times higher quality [29]. In particular, managers need to be insightful regarding psychology, behavioral psychology, leadership, teamwork, facilitation, and sociology.

5.3 A perspective for creating a new approach

To conclude, we would like to propose that the perspective necessary for the future development of SPI in Japan lies in our own experience and results.

Up until now, most of the models and standards incorporated by Japan for SPI were first announced overseas. Representative models of these include the CMM and ISO. However, we must not forget the fact that many of these models and standards used the best practices implemented by Japanese development organizations as a reference to systematize them. For example, when the CMM was being developed, staff of the SEI interviewed Japanese companies at the time, and the results they brought back to the USA for systematization had a major effect on the CMM.

However, the fact remains that many Japanese development organizations ended up focusing on understanding the CMM compiled by the SEI and implementing it exactly as it was stated. Assuming that the best practices of Japan played a major role in terms of the background of CMM development, it can be considered that the approach must have differed from the conventional one as well. In addition to this, Japan's TQC/TQM and TPS (Toyota Production System) were systematized overseas similarly to CMM, and then the results were introduced to Japan. (See the examples below.)

Examples

- TQC/TQM → The Malcolm Baldrige National Quality Award / UK-based ISO 9001 → <Introduced in Japan>
- TPS → Lean development / Agile → <Introduced in Japan>

A major issue in terms of the future of SPI in Japan is to gain an understanding of the essence of Japan's experiences so far and then refer to the methods systematized overseas in order to create models and new methodologies suitable for Japanese people. To accomplish this, it is necessary to review the technologies systematized overseas based on Japan's SPI experience from the perspective of our own experience and results, and then develop our approach accordingly. "The hints that we need regarding this new approach are not to be found in overseas models. They are right at our own feet."

6 Conclusion

The point of this paper was to explore a future direction for SPI in Japan based on the country's historical SPI efforts. To accomplish this, we started examining Japan's SPI by dividing its chronology into three phases. Based on this, we evaluated the details of each SPI activity and found that there has always been a major trend toward antinomy in terms of SPI in Japan. Finally, on the basis of this evaluation, we proposed three possible directions for future SPI in Japan. The first was "fusing organizational approaches and technology," the second was "introducing technology focused on people and a practical approach," and the third was "a perspective for creating a new approach." A particularly important perspective is that the sprout of the practical knowledge we need is already growing at our feet in the form of our past experience and results.

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