Chapter 2
The Surveys on Software Engineering Excellence

Abstract In Chap. 2, to solve the issues relating to managing innovation in the Japanese software industry as mentioned in Chap. 1, we aim to assess the achievements of the software engineering capabilities as represented by IT vendors in Japan; we additionally aim to better understand the mechanisms of how software engineering capabilities relate to IT vendors' business performance and business environment. To this end we designed a research survey to investigate software engineering excellence (SEE); we administered it together with METI and IPA. SEE was originally developed based on interviews conducted with over 50 experts in academic, business, and governmental circles in Japan and the U.S. and on literature searches in the field of software engineering in a broad sense, as we reviewed in Chap. 1. Therefore, SEE can be used to evaluate the overall software engineering capabilities of IT vendors with regard to the following seven factors: Deliverables, Project Management, Quality Assurance, Process Improvement, Research and Development, Human Resource Development, and Customer Contact. We introduced two additional primary indicators as well: Business Performance, e.g., profitability, growth, productivity, and efficiency of management, and Business Environment, e.g., origin of vendor, number of software engineers, average age of employees, business model, customer base, and corporate culture. The SEE survey resulted in 233 valid responses. We found that vendors with a larger number of software engineers tended to obtain a higher SEE score, as did vendors whose employees were older, though they tended to be less profitable. Finally, there was no significant relationship between the SEE score and operating profit ratio of the IT vendors in Japan. Because the SEE survey results are precious pieces of information in the study of the Japan's software industry, the detailed findings are demonstrated in Chap. 2, and figures relating to the survey results are included in Appendix.

Keywords Software Engineering Excellence (SEE) · Business performance · Business environment · Social survey

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2.1 Structural Model and Research Question

In order for the Japanese software industry to solve the issues relating to managing innovation in software engineering, and lead to sustained success, the first step in all achievement is to grasp an appropriate perception of the present situation in the Japanese software industry, such as software engineering capabilities, business performance, and business environment, we mentioned in Chap. 1. In other words, we need to understand how software engineering capability as a core competence (Prahalad and Hamel 1990) for the industry is significant for achieving medium- and long-term success.

Therefore, the objectives of the research in Chaps. 2 and 3 are to:

1. assess the achievements of the software engineering capabilities, as represented by IT vendors in Japan, and
2. better understand the mechanisms of how software engineering capabilities relate to IT vendors' business performance and business environment.

To achieve these objectives, we developed a measurement tool called Software Engineering Excellence (SEE). SEE was originally developed based on the interviews conducted with through over 50 experts in academic, business, and governmental circles in Japan and the U.S., and on literature reviews in the field of software engineering in a broad sense, and so on, as we surveyed in the previous Chapter (ISO/IEC/IEEE 2010; Pressman 2010; IEEE, Computer Society 2013; CMU 2014; PMI 2014; Barney 2007; Fujimoto 2003; Dodgson et al. 2008; Tidd and Bessant 2013). Therefore, SEE can be used to evaluate the overall software engineering capabilities of IT vendors from the viewpoint of the following seven factors: Deliverables, Project Management, Quality Assurance, Process Improvement, Research and Development, Human Resource Development, and Customer Contact.

We introduced two other primary indicators as well: Business Performance and Business Environment. Business Performance indicates the overall business performance of individual IT vendors, such as profitability, growth, productivity, and efficiency of the management. Business Environment expresses the company profile and structure of an IT vendor, including, e.g., origin of vendor, number of software engineers, average age of employees, business model, customer base, corporate culture. Business Environment complements the relationship between SEE and Business Performance of software vendors. The structural model of the research is shown in Fig. 2.1.

2.2 Measurement Model and Literature Review

Based on the structural model, we develop the measurement model and conducted surveys on SEE in 2005, 2006, and 2007, together with Japan's Ministry of Economy, Trade and Industry (METI), and Information-Technology Promotion Agency (IPA).

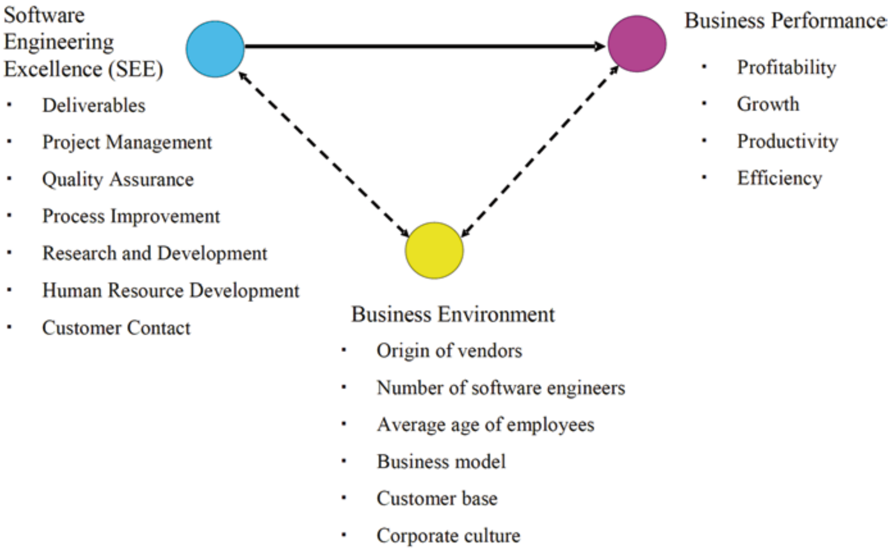

Fig. 2.1 Structural model of Software Engineering Excellence (SEE)

Software engineering capabilities are the essential management resources in the software service industry, so, in developing a measurement model in Chap. 2, we survey state-of-the-art cases in the in the software service field, through a number of experts in academic, business, and governmental circles in Japan and the U.S., paying attention particularly to the degree of rarity and imitability (Barney 2007) in the software engineering capabilities in a broad sense.

The SEE measurement model is also understood to be complementary to existing models of software engineering in a broad sense, including computer science disciplines, maturity model, and capability models, which are reviewed in Chap. 1: Software Engineering Body of Knowledge (SWEBOK), Fujimoto's manufacturing capability model, Carnegie Mellon University's Capability Maturity Model/Capability Maturity Model Integration (CMM/CMMI), and Service Science, and so on.

First of all, existing Process Improvement models in the field of software engineering are explicitly included inside the SEE model in the following way. Regarding SWEBOK (IEEE, Computer Society 2013), we reviewed the SWEBOK knowledge areas and adopted the following areas into the SEE model to address IT vendors' innovative capabilities in process and product: software requirements, software design, software construction, software testing, software maintenance, software configuration management, software engineering management, software engineering process, software engineering tools and methods, and software quality.

The manufacturing capability model (Fujimoto 2003) for the automobile industry suggests that organizational routines finally influence business performance through both deep competitiveness, e.g., quality, productivity, product and development lead-time; and superficial competitiveness, e.g., cost, delivery time, and product appeal power. Therefore, we go into greater depth, with question items of the measurement model: IT vendors' routines and deep competitiveness, i.e., Human Resource Development, Project Management, Quality Assurance, Process Improvement, Research and Development, and Customer Contact; and IT vendors' superficial competitiveness, i.e., Deliverables; and Business Performance, i.e., operating profit ratio.

Regarding CMM/CMMI (Carnegie Mellon University), we adopt into the SEE model the certification levels from one to five, so as to assess the Process Improvement factor, since we considered these levels to be a symbolic assessment measure of Process Improvement capability in software engineering.

Moreover, informed by the viewpoint of service science (Stauss et al. 2008), we see that Project Management and Customer Contact are on the borderline between user and vendor of software, so we expanded the questionnaire to include user-side items, e.g., top management involvement, and quality of user requirement specification.

Based on the above literature review and the discussions with experts in academic, business, and government circles, we came up with the SEE measurement model. The SEE measurement model has a hierarchical structure with three layers: observed responses to question items, seven detailed factors, and SEE as a primary indicator.

Software Engineering Excellence (SEE) as we have defined it consists of the following seven factors:

1. Deliverables: achievement ratios on quality, cost, speed, and productivity; understanding of project information;
2. Project Management: project monitoring, assistance to project managers, project planning capability, PMP (Project Management Professional) ratio;
3. Quality Assurance: organization, methods, review, testing, guidelines, management of outsourcers;
4. Process Improvement: data collection, improvement of estimation, assessment methods, CMM/CMMI (Carnegie Mellon University's Capability Maturity Model/Capability Maturity Model Integration);
5. Research and Development: strategy, organization, sharing of technological skills, learning organization, development methodology, intellectual assets, commoditized software, readiness for state-of-the-art technology;
6. Human Resource Development: training hours, skill development systems, incentive schemes, measurement of human resource development, moral support;
7. Customer Contact: ratio of prime contracts, scope of services offered, direct communication with customers' top management, deficit prevention, and clarification of user specifications.

Business Performance considers general performance indicators such as:

- Profitability: operating profit ratio,
- Growth: sales growth ratio,
- Productivity: sales per person,
- Efficiency: capital ratio.

Business Environment includes the following items, which are relating to the controversial issues in the Japan's software industry shown in Chap. 1, and suggested by the interviews with experts in academic, business, and governmental circles:

- Origin of vendor: manufacturer spin-off, user spin-off, or independent,
- Number of software engineers, including programmers,
- Average age of employees,
- Business model: ratio of customized development, ratio of prime contractors,
- Customer base: manufacturers, financial institute, information communication technology, public services, wholesale/retailer, services, utility, construction,
- Corporate culture: aspirations of senior managers, spirit of challenge, information sharing, agility.

2.3 Software Engineering Excellence (SEE) Surveys

2.3.1 Conduct of the SEE Surveys

Based on the measurement model of SEE survey, we administered it in 2005, 2006, and 2007, together with Japan's Ministry of Economy, Trade and Industry (METI), and Information-Technology Promotion Agency (IPA) (METI and IPA 2007; Kadono et al. 2012).

The questionnaire of SEE on the practice of software engineering and the nature of the responding company was sent to the CEOs of major Japanese IT vendors with over 300 employees, as well as the member firms of the Japan Information Technology Services Industry Association (JISA), and was then distributed to the departments in charge of software engineering.

As shown in Table 2.1, in the 2005 SEE survey, there were 55 valid responses, a response rate of 24 %; and in the 2006 SEE survey, there were 78 valid responses, a response rate of 15 %. In the 2007 SEE survey, responses were received from 117 companies, with a total of 100 valid responses, a response rate of 10 %. Although the responses are limited compared with the total IT vendors in Japan, the number of software engineers and programmers who belong to the responding companies accounts for over 30 % of the total number of them in Japan according to the re-

Table 2.1 Software Engineering Excellence surveys

Fiscal year	2005	2006	2007	Total[a]
Questionnaires sent	230	537	1000	NA
Valid responses	55	78	100	151
Manufacturer spin-off	17	27	27	42
User spin-off	15	15	20	33
Independent	23	36	53	76
Response rate (%)	24	15	10	NA

[a] Total number of unique respondents over the three surveys

port published by JISA (JISA 2014). Therefore, the SEE survey results are precious pieces of information in the study of the Japanese software industry.

In the 2005 SEE survey, we preliminarily analyzed the relationships among SEE, Business Performance and Business Environment based on data collected from 55 major IT vendors in Japan. We conducted path analysis, by which we found that SEE factors exert a direct positive impact on Business Performance, and that the Business Environment directly and indirectly (i.e., via SEE) affects Business Performance (Kadono et al. 2006). In the 2006 SEE survey, we increased the number of surveyed Japanese IT vendors from 55 to 78, in order to more deeply investigate the impact of software engineering on Business Performance and the Business Environment, as we describe the analysis results in detail in Chap. 3.

Consecutively, in the 2007 SEE survey, we collected data from the 100 major IT vendors in Japan. Since the sample size of each type of vendor in the 2007 SEE survey, i.e., manufacturer spin-off, user spin-off and independent, is large enough to perform stratified analysis, we statistically investigate the differences in characteristics attributable to vendors broken down by origin in Chap. 3. For the further analysis, such as panel analysis and longitudinal analysis, we have integrated the 233 valid responses received over the 3 years into a single database including 151 unique companies, consisting of 42 manufacturer spin-off vendors, 33 user spin-off vendors, and 76 independent vendors.

2.3.2 Calculation Results of SEE

After collecting data from vendors in 2005, 2006, and 2007, we calculated the standardized factor loadings of the seven factors—Deliverables, Project Management, Quality Assurance, Process Improvement, Research and Development, Human Resource Development, and Customer Contact—through confirmatory factor analysis, based on the responses received to the questions relevant to the measurement model described in the previous subsection.

Then we estimate the overall SEE score each year by principal component analysis, i.e., SEE2005, SEE2006 and SEE2007. For example, a histogram of deviations of the SEE2006 score is shown in Fig. 2.2. Although there are several companies with outstanding SEE scores, we consider that the SEE analysis results are appropriate for further analyses since some scores of SEE are reasonable in light of the interviews with the individual respondents we conducted. Also, a scatter plot diagram matrix of the seven factors and the overall SEE score in the SEE2006 survey is shown in Fig. 2.3. The measurement model for 2007 was modified slightly based on: the response rate for each question item; the statistical significance of each observed response obtained in the 2005 and 2006 SEE surveys; and recent changes in technology and market trends.

Figure 2.4 contains box-and-whisker plots showing that the median SEE of the manufacturer spin-off vendors is higher than that of the user spin-off vendors, which, in turn, is higher than that of the independent vendors. However, the maxi-

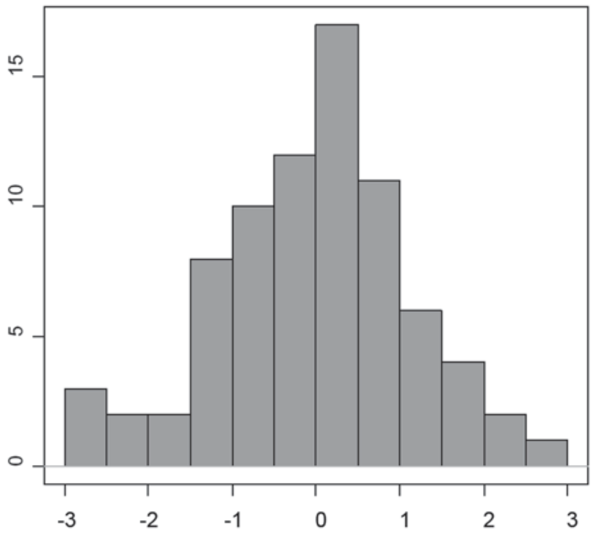

Fig. 2.2 Histogram of deviations of SEE 2006

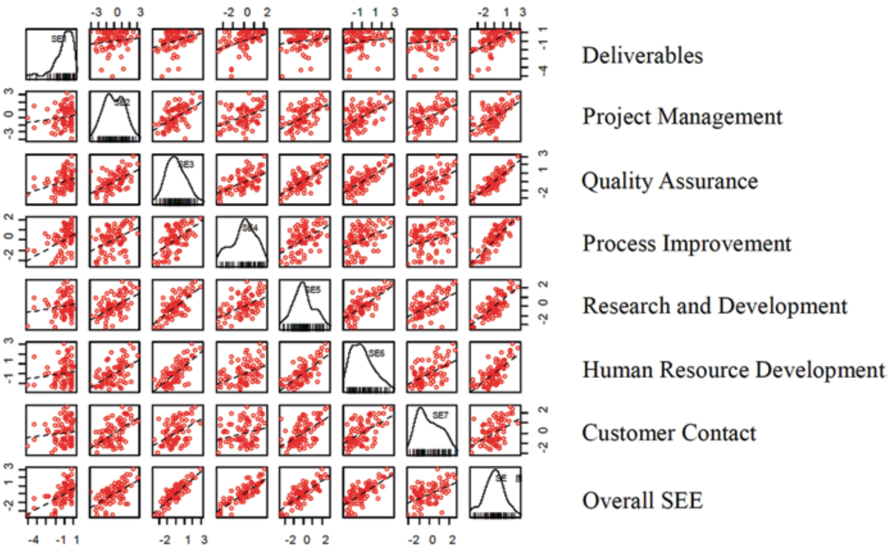

Fig. 2.3 Scatter plot diagram matrix of the seven SEE factors and over all SEE

mum SEE of the independent vendors is higher than that of the user spin-off vendors. This tendency in SEE2007 is the same as in SEE2005 and SEE2006. These findings suggest that IT user companies and IT vendors with subcontractors should select independent and manufacturer spin-off vendors through careful assessment of their software engineering capabilities.

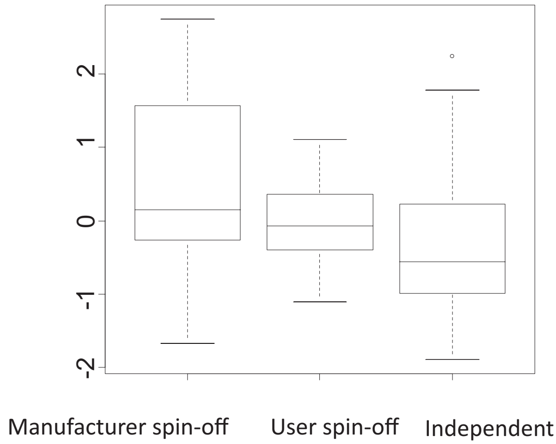

Fig. 2.4 Deviations of SEE by origin of vendors ($N=100$)

2.4 Key Findings of SEE Surveys

In this section, key findings of the SEE surveys are shown from the view point of responses to questionnaires on SEE, responses to questionnaires on Business Environment, and implications from SEE relating analyses.

Since the SEE survey results are precious pieces of information in the study of the Japanese software industry, the figures relating to the observed responses to major questionnaires relevant to the seven SEE factors at the SEE2007 survey are shown in Appendix.

2.4.1 Responses to Questionnaires on SEE

First of all, the Deliverables score of SEE is estimated using responses to the relevant question items, such as achievement ratios of quality, cost, and delivery (QCD), and productivity, and understanding of project information.

The median QCD achievement ratios are over 70% for all three types of vendor (Fig. 2.5). QCD achievement levels for user spin-off vendors tend to be higher than those for manufacturer spin-off vendors and independent vendors. This tendency was also observed in the previous study at SEE2005 and SEE2006. These findings might imply that parent companies of user spin-off vendors adequately agree with the subsidiary vendors on the quality of deliverables.

Second, the Project Management score of SEE is estimated using responses to the relevant question items: project planning capability, assistance to project managers, and project monitoring (scope, frequency).

For example, regarding project monitoring: frequency, most project monitoring operations are carried monthly or weekly (Fig. 2.6).

Third, the Quality Assurance score of SEE is estimated using responses to the relevant question items: review process, quality management organization (require-

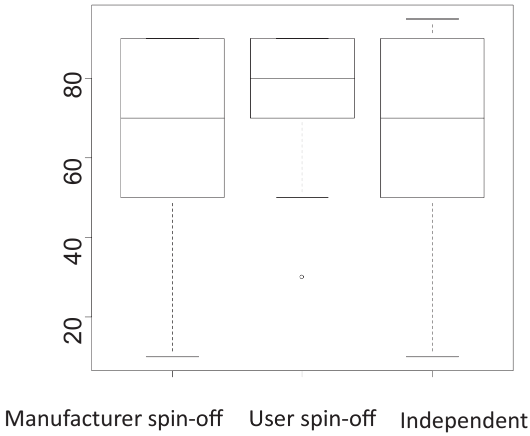

Fig. 2.5 Quality, cost and delivery achievement ratios (%) for SEE survey respondents in 2007. ($N=72$)

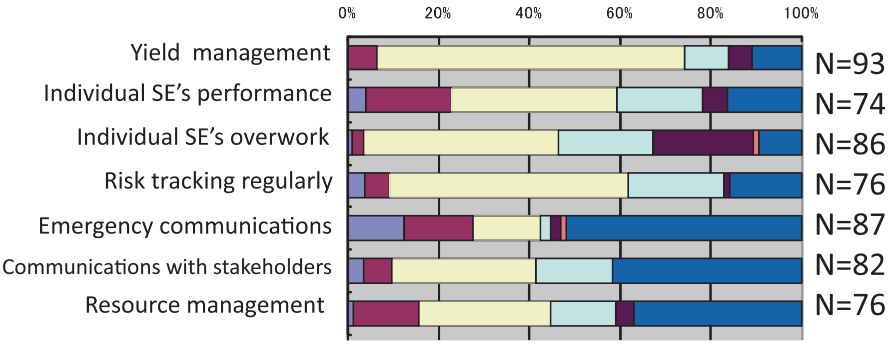

Fig. 2.6 Project monitoring: frequency. 1. annually, 2. 3/6-month period, 3. monthly, 4. weekly, 5. daily, 6. every few hours, 7. anytime

ment definition, schematic design, detail design, development, test, operation and manual), and management of outsources.

In terms of the Review process, almost half of IT vendors carry out quality reviews according to standard procedures of corporates through the project management process, i.e., requirement definition, schematic design, detail design, development, test, operation and manual (Fig. 2.7).

Fourth, the Process Improvement score of SEE is estimated using responses to the relevant question items: objectives management, data collection, data utilization, and improvement of estimation

With respect to Data collection for process improvement, some companies have collected data for process improvement on bugs, quality assurance, productivity, quality of life (QOL), technical skills, and cost for more than 20 years (Fig. 2.8).

Fifth, the Research and Development (R&D) score of SEE is estimated using responses to the relevant question items: strategy, organization, learning organiza-

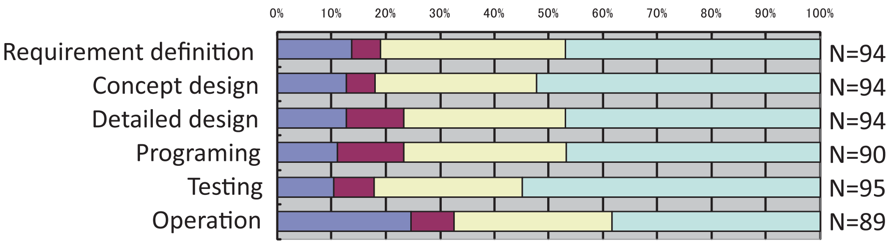

Fig. 2.7 Review process. 1.no review procedure, 2. little review with procedure, 3. half review with procedure, 4. almost review with procedure

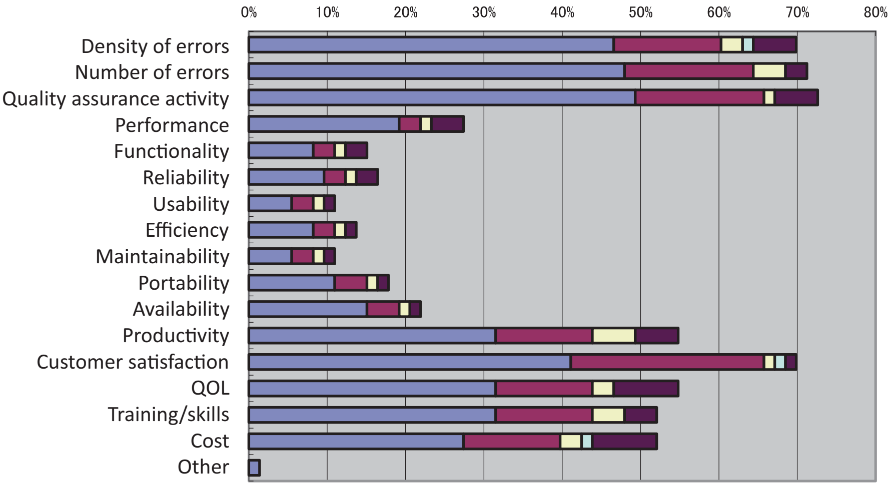

Fig. 2.8 Accumulated number of years of data collection for process improvement ($N=73$). 1. –5 years, 2. 6–10 years, 3. 11–15 years, 4. 16–20 years, 5. 20– years

tion, readiness for state-of-the-art technology, development methodology, reuse of software resources, and effect of R&D.

Regarding Research and development (R&D) strategy, half of IT vendors have R&D strategies at least of a couple of years. On the other hand, 40 % of them have either no R&D strategies or single year R&D plans (Fig. 2.9).

Sixth, the Human Resource Development score of SEE is estimated using responses to the relevant question items: ratio of prime contracts, direct communication with customers' top management, understanding of proposal by vendors' top management, scope of services offered, clarification of user requirements, and prevention against unprofitable project.

One of the SEE questionnaires used to measure Human Resource Development asks about the number of training hours for new recruits. For new recruits, the median is over 400 training hours per year (Fig. 2.10), whereas for other experienced software engineers, another Human Resource Development measurement item queried in the survey, the median is almost 40 h per year (Fig. 2.11). This tendency

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