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A Survey on Management of Software Engineering: Causal Relationship on Independent Vendors in Japan

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***Abstract*— The purpose of this study is to clarify the mechanism of how software engineering capabilities relate to the business performance of IT vendors based on the continuous researches in 2005, 2006 and 2007. To end this, we developed a structural model, including the Software Engineering Excellence (SEE) indicator which consisted of deliverables, project management, quality assurance, process improvement, research and development, human resource development and customer contact. By analyzing the data collected from 100 major IT vendors in Japan in 2007, we found that the relationships among the factors differ significantly from the origins of the vendors: IT makers, IT users and independent vendors. Particularly in this paper, we investigated independent vendors more deeply by conducting path model analysis and found the unique causal relationship of independent vendors in Japan. Simultaneously, we reproducibly observed that the effort level on human resource development, quality assurance and project management made better performance of customer contact, research and development and process improvement at the independent vendors in 2007.**

***Index Terms*— software engineering capability, business performance, competitive environment, statistical analysis**

I. INTRODUCTION

Most companies that use enterprise software in Japan have not been fully satisfied with the quality, cost, speed and productivity of software that IT vendors deliver. Simultaneously, IT vendors in Japan are facing drastic changes in their business environment, such as technology innovations and new entrants from China and India. Also, the issues in the IT industry in Japan, such as the multilayer subcontractors and the business model depending on custom-made applications for domestic market orientation, have been pointed out over times [3, 9].

In order for the IT industry in Japan to meet these challenges, an important step is to understand the extent to which software engineering is a core competence for achieving medium- and long-term success. To do so, we designed the research on software engineering capabilities and conducted it in 2005, 2006, and 2007[7, 8].

The objectives of the study were:

- to assess the achievement of software engineering by IT vendors in Japan, and
- to better understand the mechanism of how software engineering capabilities relate to the business performance as well as competitive environment of IT vendors in Japan.

To achieve these objectives, we developed a measurement tool called "Software Engineering Excellence (SEE)", which can evaluate the overall software engineering capabilities of IT vendors from the viewpoint of deliverables, project management, quality assurance, process improvement, research and development, human development, and contact with customers. Also, we introduced other indicators: business performance and competitive environment. The competitive environment complements the relationship between SEE and the business performance of the software vendors.

In the SEE2005 survey, we analyzed the relationship among software engineering excellence (SEE), business performance and competitive environment based on the data collected from 55 major IT vendors in Japan[7]. As we conducted the path analysis, we found that software engineering excellence (SEE) has a direct positive impact on business performance and that the competitive environment directly as well as indirectly (i.e., via SEE) affects business performance.

In the SEE2006 survey, we modified the measurement model used in SEE 2005 and 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, as well as the competitive environment[8]. In particular, in this study we focus on the relationships among factors of SEE, the competitive environment, and business performance as measured by operating profit ratio. By analyzing the data collected from 78 major IT vendors in Japan, we found that superior deliverables and business performance were correlated with the effort expended particularly on human resource development, quality assurance, research and development and process improvement.

In 2007, we modified the measurement model again and analyzed the data collected from 100 major IT vendors in Japan.

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We found the relationships among the factors differ significantly from the origins of the vendors: IT makers, IT users and independent vendors. Particularly in this paper, we investigated independent vendors more deeply by conducting path model analysis and found the unique causal relationship of independent vendors in Japan. At the same time, we reproducibly observed that the effort level on human resource development, quality assurance and project management made better performance of customer contact, research and development and process improvement at the independent vendors in 2007, as we found such overall tendency in 2006.

II. Research Method

A. Structural Model

We assume the following research questions on the relationship among the three primary indicators, i.e., software engineering, business performance, and competitive environment, as shown in Fig. 1.

Research question 1: the "software engineering excellence (SEE)" has a positive impact on "business performance".

Research question 2: the "competitive environment" directly and indirectly (i.e., via SEE) affects "business performance".

Here, "software engineering excellence (SEE)" expresses the extent to which IT vendors can put software engineering into practice. SEE is a measurement tool for evaluating the overall capabilities of software engineering of IT vendors from the viewpoints of deliverables, project management, quality assurance, process improvement, research and development, human development, and contact with customers.

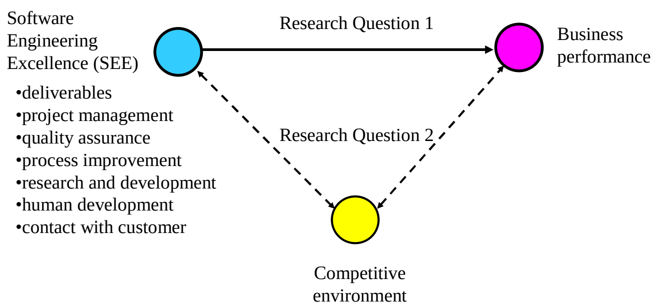

Fig. 1: Structural model.

"Business performance" expresses the overall business performance of individual IT vendors, such as profitability, growth, and management efficiency. "Competitive environment" expresses the company profile of IT vendors as well as the business environment in which the vendors work, e.g., number of software engineers, business model, and average age of employees.

B. Measurement Model

Our measurement model of software engineering excellence (SEE) was originally developed through the interviews with over 30 experts in the industry and literary searches [1, 2, 4, 10, 11]. The SEE measurement model has a hierarchical structure with three layers: observed responses, seven detailed concepts, and SEE as a primary indicator, as we developed in our research on IT management effectiveness [5].

The measurement model at SEE2007 has been modified based on the response rate of each question item and the statistical significance of each observed responses at SEE2005 and SEE2006. For example, the observed responses such as readiness for state-of-the-art technology, moral support, and clarification of user specification were newly added to the measurement model of SEE2006 as a result of feedback from the respondents to SEE2005 and the interviews with the experts. Also, achievement ratio of productivity and grip on project information were newly added to the measurement model in SEE2007 based on the experiences at SEE2006. The measurement model of SEE2007 was as follows:

- Software engineering excellence (SEE)
  - deliverables: achievement ratio of quality, cost, speed, and productivity
  - project management: project monitoring, assistance to project managers, project planning capability, ratio of PMP(Project Management Professional)
  - quality assurance: organization, method, review, testing, guideline, management of outsourcers
  - process improvement: data collection, improvement of estimation, assessment method, CMM/CMMI [2]
  - research and development: strategy, organization, sharing technological skills, learning organization, development methodology, intellectual assets, commoditized software, readiness to state-of-the-art technology,
  - human development: training hours, skill development systems, incentive schemes, measure of human development, moral support
  - contact with customers: ratio of prime contracts, scope of service offered, direct communication with customer's top management, deficit prevention, clarification of user specification

In addition to SEE, we assume two primary indicators, business performance and competitive environment as follows.

- Business performance
  - profitability: operating profit ratio
  - growth: annual sales growth
  - management efficiency: return on equity
- Competitive environment
  - origin of IT vendors: IT makers, IT users, and independent vendors,
  - number of software engineers including programmers
  - average age of employees
  - business model: ratio of customized development, ratio of development based on mainframe computer, ratio of prime contractors

C. *Hypothesis at SEE2007 based on the result at SEE2006*

At SEE2006, by a trial and error method, we succeeded in constructing a well-fitted path model (CFI = 1.0), where all the existing path coefficients are significant at the 5% level (Fig. 2). Therefore, regarding the research question 1, based on the result of SEE2006, we hypothesize of the path model of SEE2007.

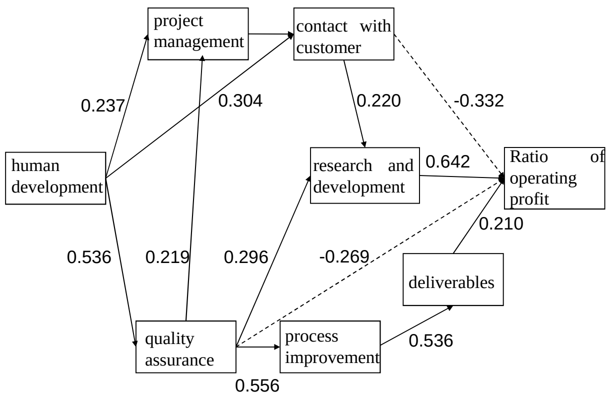

Fig. 2: Result of path analysis among factors of SEE and business performance.

In terms of the research question 2, we newly come up with factors based on principal component analysis of the competitive environment in the following section.

III. Survey on Software Engineering Excellence (SEE2007)

To research on the questions in the previous section, we conducted the third survey on Software Engineering Excellence (SEE2007). In this survey, we designed a questionnaire on the practice of software engineering and the nature of the company. This questionnaire was sent to the CEOs of 1000 major Japanese IT vendors with over 300 employees as well as the member firms of Japan Information Technology Services Industry Association (JISA), and was then distributed to the departments in charge of software engineering.

Responses were received from 117 companies and valid responses totaled 100 at SEE2007 (response rate of 10%), while valid responses numbered 55 (response rate of 23%) at SEE2005 and 78 (response rate of 15%) at SEE2006, respectively. At SEE2007, 27 are from makers, 20 are from users and 53 are from independent vendors.

The measurement model in the previous section is fitted to the data by confirmatory factor analyses to estimate the scores of software engineering excellence (SEE) in the same way as we developed at SEE2005 as well as SEE2006.

Fig. 3 shows a histogram of the deviations of software engineering excellence (SEE) of 100 IT vendors. Although there are several companies with outstanding SEE scores, we consider that the result of SEE analysis is appropriate for further analyses since some scores of SEE are reasonable in light of the results of the interviews with the individual respondents.

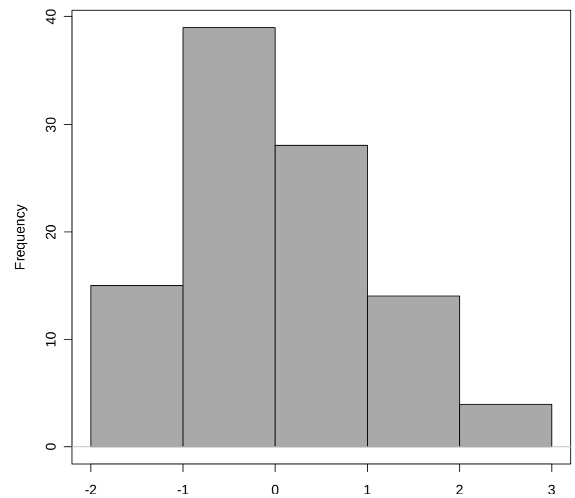

Fig. 3: Histogram of deviations of SEE.

Fig. 4 contains a box-and-whisker plots which shows that the median software engineering excellence (SEE) of vendors who were originally makers of IT is higher than that of vendors who were originally users of IT. Also, the median SEE of vendors who were originally users of IT is higher than that of independent vendors. However, the maximum SEE of independent vendors is higher than that of IT users. This tendency in SEE2007 is the same as that in SEE2005 as well as SEE2006.

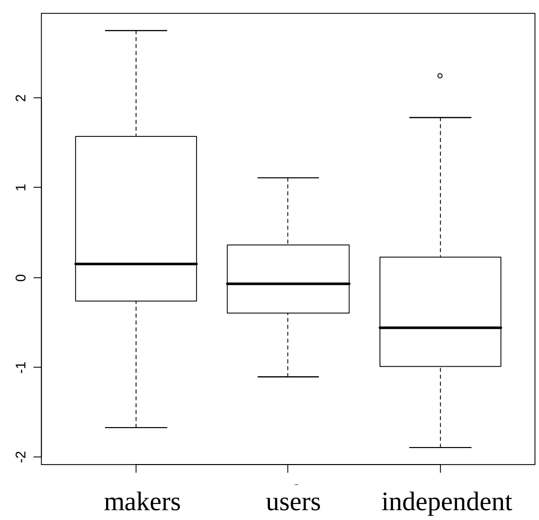

Fig. 4: Deviation of SEE by origin of vendors

For instance, regarding the achievement ratio of QCD, which is one of the question items to measure deliverables at SEE, the median achievement ratios of QCD are higher than 70% (Fig. 5). Also, the achievement levels of QCD at IT user companies

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tend to be higher than those of IT makers and independent vendors. This tendency was also observed in the previous study at SEE2006.

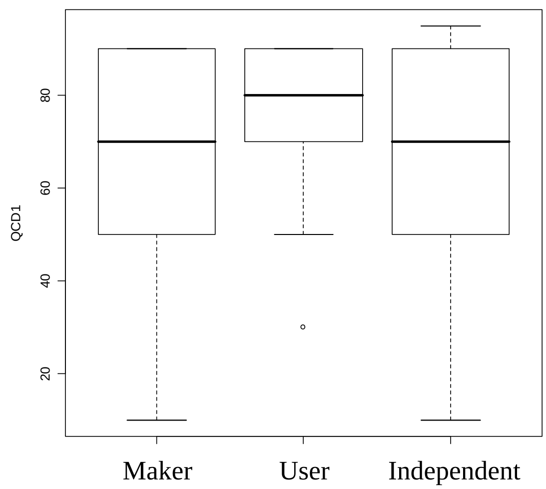

Fig. 5: Achievement ratio of quality, cost, and delivery(%).

In terms of training hours for new recruits, which is one of the question items to measure human development at SEE, the median hours for new recruits is over 400 hours per year (Fig. 6), while the median hours for software engineers except new recruits, which is another question item to measure human development at SEE is almost 40 hours per year. This tendency was also observed in the previous study at SEE2005 and SEE2006. IT makers tend to invest more time on the training for the engineers relatively.

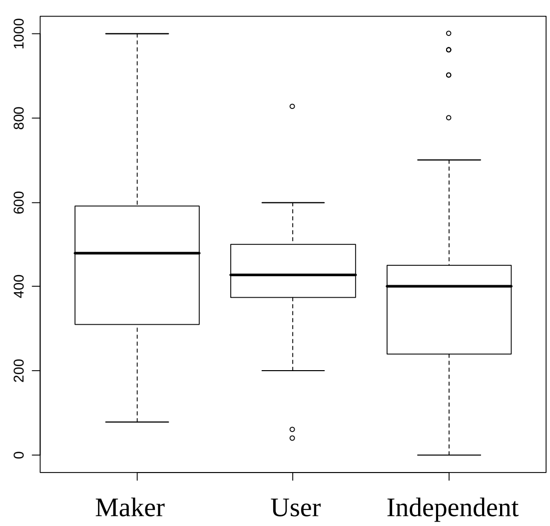

Fig 6: Training hours for new recruits (hours).

IV. Result of Analysis

In this section we analyze the relationships among SEE, competitive environment and operating profit ratio by the origins of vendors: IT makers, IT users, and independent vendors.

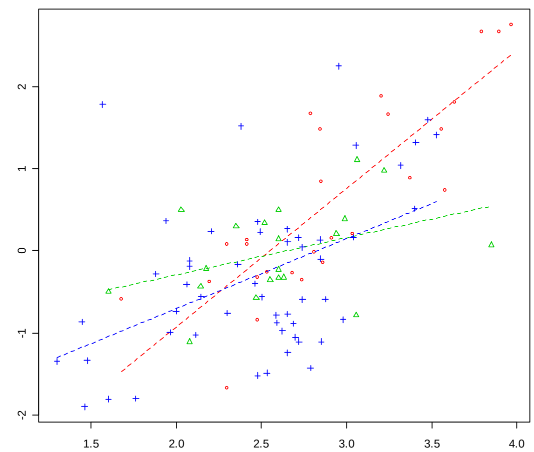

Fig. 7: Number of software engineers vs. SEE.
(. maker, △user, +independent)

Fig. 7 shows that vendors who have a larger number of software engineers tend to score higher SEE in any type of vendors. This tendency was similar to that of the previous study at SEE2005 and SEE2006. We need to further investigate the advantage of scale in terms of capability management of software engineering.

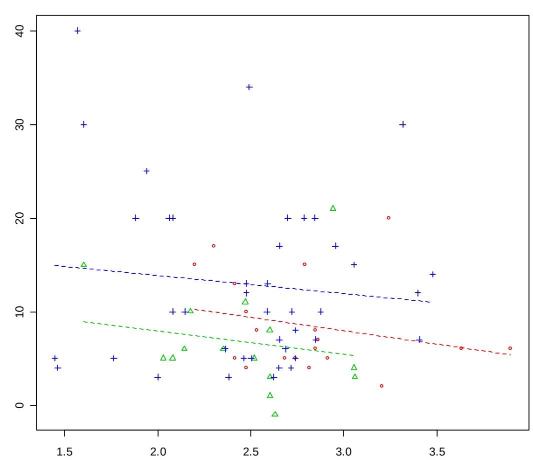

Fig. 8: Number of software engineers vs. operating profit ratio. (. maker, △user, +independent)

However, as shown in Fig. 8, vendors who have a larger number of software engineers tend to be less profitable in any type of vendors. This tendency was also reproducible in that of the previous study at SEE2005 and SEE2006.

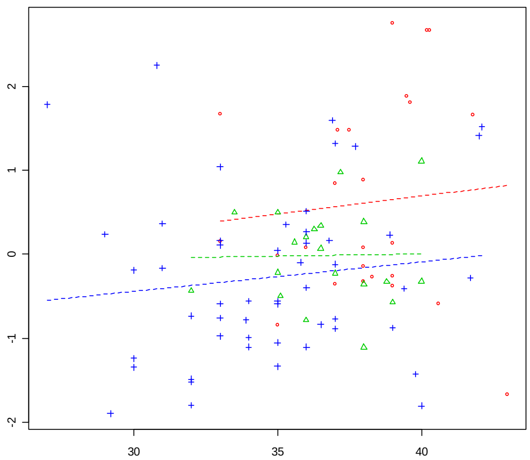

Fig. 9: Average age of employees vs. SEE.
(. maker, △user, +independent)

Fig. 9 shows that vendors whose employees are older tend to score higher SEE, except the vendors who originally IT user firms. Learning effect of senior engineers remains a matter of debate, particularly in the vendors who originally IT user firms.

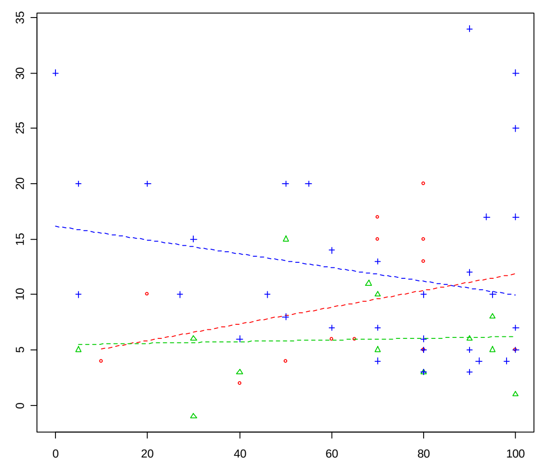

Fig. 10: Custom made vs. operating profit ratio.
(. maker, △user, +independent)

Fig. 10 shows the relationships between the ratio of custom software development, which does not utilize package software, and operating profit ratio. Only vendors who were originally IT makers tend to be more profitable as they adopt a custom-made approach. In Japan, IT client enterprises prefer a custom-made approach to package software in general. We need to further consider the pros and cons of utilization of package software in Japan, compared with th situation in other Asian countries and the U.S.

Fig. 11 shows that vendors who have a higher software engineering excellence (SEE) tend to be slightly more profitable at IT vendors who were originally makers. Further analysis of causal relationships of IT independent vendors among the factors would be conducted later.

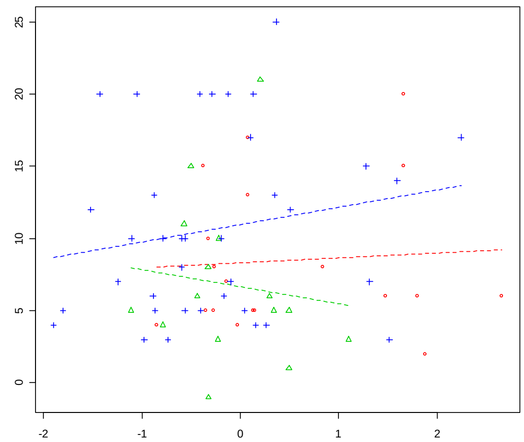

Fig. 11: SEE vs. operating profit ratio.
(. maker, △user, +independent)

We conducted principle factor analysis based on the following items of competitive environment: annual sales volume, sales percentage by industries (manufacturers, financial institute, information technology/communications, public services, wholesale/retailer, services, utility, construction), sales bias, customer sales, outsourcing, board member with MBA holder and technologist, number of software engineers, ratio of software engineers, average age of employees.

Based on the results of the principle factor analysis in Table 1, we identified the following five factors: scale (Factor1), manufacturers –oriented (Factor2), sales bias (Factor3), non-manufacturers-oriented (Factor4), ratio of software engineers (Factor5).

Table 1: Result of principle factor analysis of competitive environment

	Factor1	Factor2	Factor3	Factor4	Factor5
SS loadings	1.856	1.704	1.701	1.631	1.573
Proportion Var	0.098	0.090	0.090	0.086	0.083
Cumulative Var	0.098	0.187	0.277	0.363	0.446

Test of the hypothesis that 5 factors are sufficient.
The chi square statistic is 95.61 on 86 degrees of freedom.
The p-value is 0.224

On the basis of the results of the analyses above, we constructed a path model that consists of all seven factors of SEE, the ratio of operating profit as well as the five factors of competitive environment above.

In this paper, we are focusing on the causal relationship of the independent IT vendors, since they are the most correlated between SEE and operating profit ratio of the three types of vendors in Fig 11 and since their SEE could create operating profit ratio without depending on capital ties to their customers essentially.

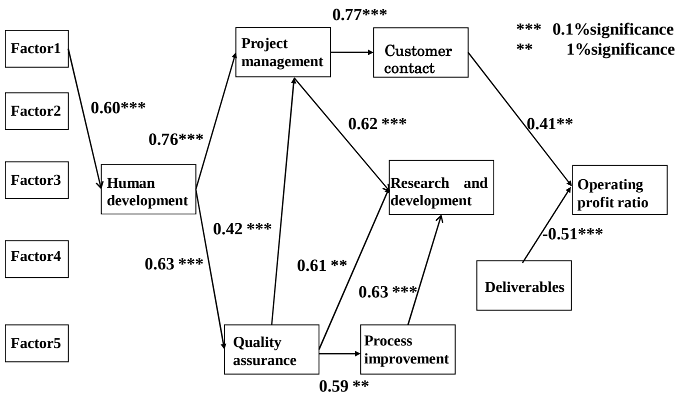

Fig. 12: Result of path analysis among factors of competitive environment, factors of SEE and business performance.

By using a trial and error method, we succeeded in constructing a well-fitted path model (p-value of chi square statistic is 0.0120. CFI = 0.8546, GFI = 0.7417), where all the existing path coefficients are significant at the 1% level. We found the following direct influences (Fig.12):

- Regarding competitive environment, only the scale factor (Factor 1) such as sales volume and the number of software engineers positively affects human development
- Within the SEE factors, human development is positioned in the uppermost stream and upper relationships at SEE2007 are similar to those at SEE2006 in Fig. 2.
- Human development has positive impact on quality assurance and project management as SEE2006.
- Quality assurance has a direct positive impact on process improvement, project management, and research and development.
- Process improvement has positive impact on research and development.
- Project management has a direct positive impact on customer contact and research and development.
- However, research and development has no impact on the ratio of operating profit directly. This tendency is different the result of the previous study at SEE2005and SEE2006.
- On the other hand, customer contact has a direct positive impact on operating profit ratio.
- Finally deliverable has a direct negative impact on operating profit ratio. This could implicate that the achievement of deliverables does not pay off.

V. Conclusion

In this study, we modified the measurement model of SEE and analyzed the relationship among SEE, business performance and competitive environment based on the data collected from 100 major IT vendors in Japan.

We found the relationships among the factors differ significantly from the origins of the vendors: IT makers, IT users and independent vendors. Particularly in this paper, we investigated independent vendors more deeply by conducting path model analysis and found the unique causal relationship of independent vendors in Japan. Simultaneously, we reproducibly observed that the effort level on human resource development, quality assurance and project management made better performance of customer contact, research and development and process improvement at the independent vendors in SEE2007, as we found such overall tendency in SEE2006.

To better understand the reality and issues facing Japan's software industry in the medium- and long-term, we suggest that future studies be conducted as follows:

- time series analysis including financial data,
- global benchmarking,
- further refinement of the measurement model and analysis,
- further analysis by types of vendors, e.g., vendors from makers, vendors from users, and independent vendors, and
- data collection over a wider range of IT vendors.

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References

[1] Erik Brynjolfsson, (2004) *Intangible Asset*, Diamond.
[2] Carnegie Mellon University, Software Engineering Institute, http://www.sei.cmu.edu/cmmi/.
[3] Micheal A. Cusumano, (2004) *The Business of Software*, Free Press.
[4] Takahiro Fujimoto, (2003) *Nouryoku Kouchiku Kyousou*, Chuohkouronshinsya (in Japanese).
[5] Yasuo Kadono, (2004) *Evolution of IT Management Creating Business Value*, Nikkagiren.
[6] Yasuo Kadono, Hiroe Tsubaki, (2006) "Development of IT Management Effectiveness and Analyses of Japanese Companies," Journal of Japanese Association for Management Information, Vol.14, No.4, pp.69-83.
[7] Kadono, Y., H. Tsubaki, and S. Tsuruho (2006). "A Study on the Reality and Economy of Software Development in Japan," The sixth Asia Pacific Industrial Engineering Management Systems Conference, Bangkok, Thailand, pp.1425-1433.
[8] Kadono, Y., Tsubaki H., Tsuruho S. (2007). "A Survey on Management of Software Development in Japan," World Congress on Engineering and Computer Science, San Francisco, USA: 983-988.
[9] Kadono, Y. 2007. *The Issues on IT Industry in Japan*, Nikkei Net . http://it.nikkei.co.jp/business/news/index.aspx?n=MMITac00 0017122007
[10] Yoshihiro Matsumoto, (2005) *Application of SWEBOK to Software Development*, Ohmsha.
[11] Ministry of Economy, Trade and Industry, (2006) *Report on Software Industry*.