Studies on the Software Engineering Capabilities in Japan from the Viewpoint of Applied Statistical Analyses

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Abstract:

Based on the data from the 233 valid responses we had received to the 2005, 2006, and 2007 surveys on software engineering capabilities from 151 unique firms, we have performed several statistical analyses for the specific research questions. In this paper, we introduce primary analysis results using the statistical analyses, such as factor analysis, cross-section analysis, stratified analysis, and panel analysis, and discuss future work.

1. Introduction

The information service industry is a 10.5 trillion yen market in Japan, which includes 7.6 trillion yen in software development and programming. In 2009, orders for software totaled 6.4 trillion yen, accounting for 60.3% of the entire information service industry (METI, 2010). Like the rest of the world, many companies in Japan that use enterprise software have not been fully satisfied with the quality, cost, speed and productivity of software that IT vendors deliver. At the same time, IT vendors in Japan are facing drastic changes in their business environment, such as technology innovations and new entrants from emerging countries all over the world. There are issues that are characteristic of the IT industry in Japan, such as multilayer subcontractors and business models being dependent on custom-made applications for the domestic market (Cusumano, M., 2004).

In order for the IT industry in Japan to meet these challenges, an important step is to understand how software engineering capability is significant for achieving medium- and long-term success. Therefore, we designed a research survey on software engineering excellence and administered it in 2005, 2006 and 2007 with the Japanese Ministry of Economy, Trade and Industry (METI).

The objectives of the research were to:

- assess the achievements of the Japanese software engineering capabilities, as represented by IT vendors,
- 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), which can evaluate the overall software engineering capabilities of IT vendors based on several factors: deliverables, project management, quality assurance, process improvement, research and development, human development, and customer contact. We introduced two other indicators as well: business performance and business environment. The business environment complements the relationship between SEE and the business performance of software vendors.
2. Survey on Software Engineering Excellence (SEE)

The model we used to measure SEE was originally developed through interviews with over 50 industry experts in Japan and the U.S. and literature searches (Barney, 2007; Carnegie Mellon University; Fujimoto, T., 2003; IEEE, 2004; Ministry of Economy, Trade and Industry). Based on these considerations, 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 concepts, and SEE as a primary indicator. SEE as we have defined it consists of the following seven concepts:

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

Based on the measurement model, we conducted surveys on Software Engineering Excellence in 2005, 2006 and 2007 with Japan’s Ministry of Economy, Trade and Industry. We designed a questionnaire on the practice of software engineering and the nature of the respondent’s company. This questionnaire 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.

Responses were received from 117 companies with a total of 100 valid responses to the 2007 survey, a response rate of 10%. There were 55 valid responses, a response rate of 24%, for the 2005 survey and 78 (response rate of 15%) for 2006. For this paper, we integrated the 233 valid responses received over the three years into a new database including 151 unique companies consisting of 42 maker-turned vendors, 33 user-turned vendors and 76 independent vendors.

3. Statistical Analyses of SEE Studies

(1) Exploratory factor analysis
After collecting data from vendors in 2005, 2006 and 2007, we performed exploratory factor analysis and calculated the factor loadings and standardized factor scores of seven factors: deliverables, project management, quality assurance, process improvement, research and development, human development and customer contact, based on the responses received to the questions relevant to the measurement model. For example, the SEE deliverables score is estimated using responses to the relevant question items, such as achievement ratios of quality, cost, and delivery (QCD), productivity, and understanding of project information, in the measurement model.

(2) Cross-section analysis

In the 2006 SEE survey, we performed analysis on the relationships among the SEE factors and business performance as measured by operating profit ratios based on the structural hypothesis (Kadono, Tsubaki, Tsuruho, 2007). By analyzing the data collected from 78 major IT vendors in Japan, we found that superior deliverables and business performance have significant correlations (5% level) with effort expended, particularly on human resource development, quality assurance, research and development and process improvement.

(3) Stratified analysis

Regarding the differences among types of vendors, the causal relationships differ significantly depending on the vendors’ origin, i.e. whether a business is a maker-turned vendor, a user-turned vendor or an independent vendor (Kadono, Tsubaki, Tsuruho, 2009). In the 2007 SEE survey, the sample size was enough to perform stratified analysis. Then, we constructed a well-fitted path model of the maker-turned vendors (CFI = 1.0), where all the path coefficients are positive significantly at the 5% level. Although the causal relationship of the maker-turned vendors are similar to the overall structure in the 2007 SEE survey, it emphasizes that the paths from human development through quality assurance, project management and process improvement toward deliverables are connected positively and highly significantly. In addition, the paths from human development to research and development through project management and quality assurance are positively and significantly.

(4) Panel analysis

We conducted a panel analysis of the seven SEE factors based on the data from the 233 valid responses we had received to the 2005, 2006, and 2007 surveys from 151 unique firms (Kadono, Tsubaki, Tsuruho, 2010).

The panel analysis results indicate the following:

- Vertically, (year-to-year) IT vendors build on SEE factor levels that they have achieved thus far.
- Horizontally (in a year), the structural consistency over the different years leads us to understand that there are three paths toward improving the level of deliverables through human development via:
  - Project management and customer contact that suggest marketing innovation,
  - R&D that suggests product innovation, and
  - Quality assurance and process improvement that suggest process innovation.
- Diagonally, the factors that directly influence factors in the following year point to positive mid-term effects such as human development in 2005 leading to R&D improvements in 2006 and process improvement in 2005 influencing deliverables in 2006.

- Several negative paths imply that effort invested in some factors did not pay off, at least during the duration of this research. They might, however, be expected to have long-term effects, e.g., from R&D in 2005 and 2006 to deliverables in 2006 and later.

4. Conclusion and Future Work

We have performed several statistical analyses, such as factor analysis, cross-section analysis, stratified analysis, and panel analysis, using the SEE survey data as well as financial data of the firms, for the specific research questions. In addition to the analyses in this paper, we are planning to perform latent growth curve analysis (Meredith and Tisak, 1990) using data collected from the 151 unique firms in the survey on SEE and financial data of these firms for future study.

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References

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