New Framework for Manufacturing Innovation by Systems Engineers

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Faced with a massive trend toward open environments and the changes surrounding them, the Fujitsu Group has been promoting four innovation initiatives—Design Innovation, Production Innovation, Maintenance Innovation, and SE Work Style Innovation—to maintain a high level of technical capabilities among its systems engineers (SEs). Over the last two and a half years, these initiatives have produced many results including guidelines for defining requirements, basic design guidelines, and a common maintenance framework using application portfolio management, but they have also revealed a number of issues. To resolve these issues, Fujitsu has decided to take the four innovation initiatives to a second stage and add a new initiative called Human Resources Innovation to form five innovation initiatives, which are slated to run for the next three years. These five innovation initiatives are not, however, the final objective. The Design, Production, and Maintenance Innovation initiatives will be consolidated into a unified system of knowledge that can provide value to customers, and the SE Work Style and Human Resources Innovation initiatives will lead to next-generation SEs with the skills for exploiting that knowledge. The objective is to create a structure in which knowledge and human resources are synchronized to create value in an ongoing manner.

1. Introduction

Have Fujitsu's technical capabilities dropped? In particular, have the technical capabilities of Fujitsu's systems engineers (SEs) who deal directly with customers lost their luster? That is what can be read in some public reports. Is it true? The answer is a resounding "no". The technical expertise of the Fujitsu Group is as advanced as ever. However, the basic premises for discussions of technical capabilities are changing, and when viewed in the light of these changes, Fujitsu has not been coming up with answers. This, unfortunately, appears to be the reason for the negative evaluation that Fujitsu has received from some quarters.

Today, the Fujitsu Group still has high-class individual elemental technologies. In the past, it was considered acceptable to deliver new technologies in a linear manner, but today, an optimal combination of them needs to be delivered at low cost in a relatively short period of time. In short, having high technical capabilities now means possessing even more elemental technologies while also having complex and advanced methods for connecting them. This means having to find an optimal solution from a large number of combinations, which can be difficult. This is the challenge that SEs in the Fujitsu Group now face.

The solution is to provide a "proven model". Instead of looking for new combinations for each and every problem location, a better approach is to expand upon proven results; that is, to treat past achievements as knowledge. Proven results

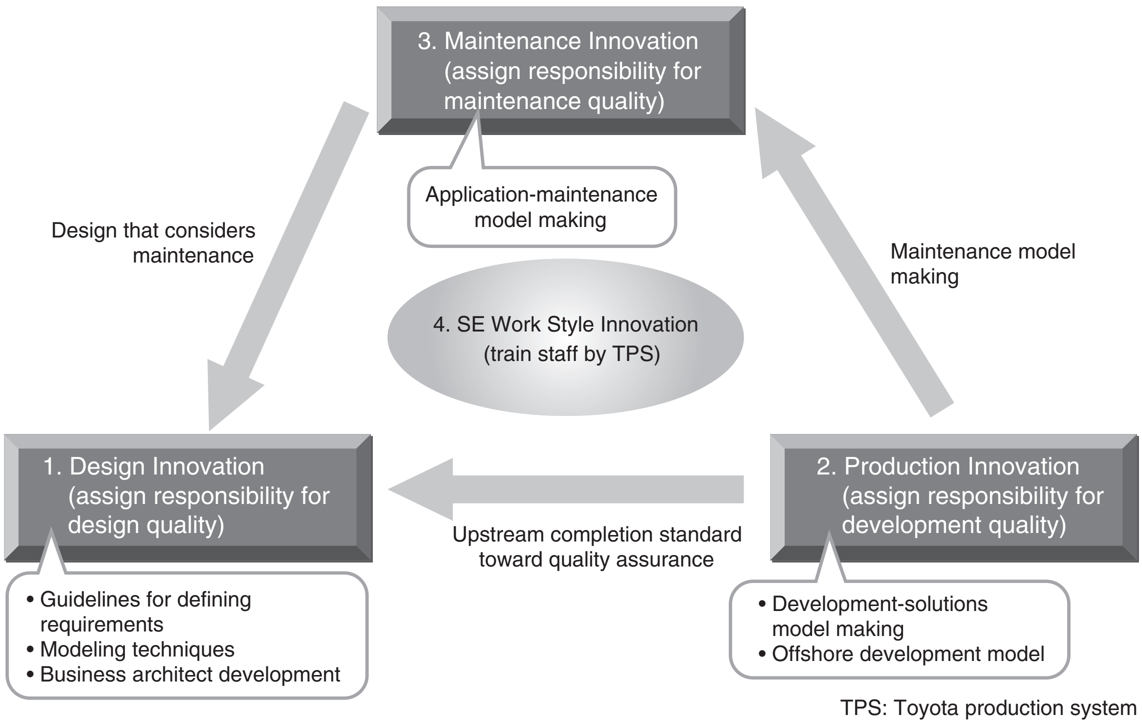

Figure 1
Stage 1: Four innovation initiatives.

are being accumulated every day in Fujitsu Group projects. As a result, good case studies can be extracted at a later date as "models" and utilized in other projects. The four innovation initiatives[1] behind this process form a mechanism for breaking down SE activities into four categories and extracting knowledge that should be shared from each category so that it can be put to good use in new projects.

As an introduction to this special issue, this article discusses future directions in manufacturing innovation. Section 2 describes the four innovation initiatives applied to date and Section 3 describes their extension with the addition of one more initiative.

2. Innovation initiatives: Stage 1

2.1 Purpose of the four innovation initiatives

The extensive know-how accumulated by the Fujitsu Group over many years on system development and the provision of solutions services forms the basis of Fujitsu's System Development Architecture & Support facilities (SDAS),[2] a comprehensive system development methodology that was established by Fujitsu to provide tools and a development framework. However, customs unique to Japan, such as a procrastinating culture hesitant to assign anyone the task of preventing vague requirements and the high mobility of engineers due to the formation of multiple subcontracting teams, have formed a big obstacle to the delivery of SDAS benefits to customers, which has created a major problem. At the same time, efforts to verify technology in an open-systems environment have resulted in a trend toward highly granular tools, which, in turn, has made it difficult to get a comprehensive perspective.

To respond appropriately to customer calls for the early provision of inexpensive, high-quality systems, Fujitsu established four innovation initiatives to systematically reorganize technology, know-how, development processes, and human resources on the basis of the flow of value provided to customers (business process). It also set up a framework for surveying the cyclic process of design → production → maintenance (and onto the next design period) and determining how SEs can provide even greater value within this cycle (**Figure 1**).

2.2 Results to date

These activities have produced a variety of results over the last two and a half years, such as the ones listed below.

1) Guidelines for defining requirements and basic design guidelines
2) EZDeveloper (an application framework)
3) Maintenance framework based on application portfolio management
4) Improvement activities based in the field

Details of these measures are provided in the articles in this special issue. We point out here that, since they have only recently been established, they will need to undergo repeated revisions before they reach a mature stage. It is also extremely important that these measures be used thoroughly. The fountainhead of Fujitsu's knowledge is always business sites: refining knowledge and making it more effective starts in the field.

2.3 New issues

The four innovation initiatives, while producing the results described above, have also revealed certain issues. To begin with, design, production, and maintenance are, in the end, only part of the system (or service) lifecycle. In essence, repetition of this cycle creates customer value on an ongoing basis. Accordingly, design, production, and maintenance must be constructed on the same baseline in a continuous fashion as a unit. To give an example, "requirements" in design are converted into "specifications", which are then embodied as a "program" or "subsystem" (a set of programs) in production and eventually used as "functions" at the point of maintenance (or during use). These representations, while each having a different form, must be identical in content. As long as the design, production, and maintenance innovations progress independently, the possibility of a gap or break between them cannot be denied. To prevent such gaps from forming, Fujitsu felt the need for a second stage of innovation initiatives that would establish a basic constituent element (repository) running throughout the system or service and provide an integrating effect while describing how the repository would appear in each process and how it would change in combination with process transitions.

Another issue that arose is the need to reevaluate the human resources we call engineers. While there have been attempts to clarify guidelines on how an SE should carry out his or her work, the SE Work Style Innovation initiative seeks to answer various SE-related questions, such as what does the position of SE mean in terms of human resources, what technologies must an SE be proficient in, what skills outside technologies should an SE have, and should all the people who currently call themselves SEs actually be called such. Questions such as these must be answered if customers are to understand the benefits of solutions—Fujitsu's main line of business—and make good use of them.

3. Innovation initiatives: Stage 2

To address the issues discussed above, innovation activities are entering a second stage, which has two features. The first is the passing of a consistent, basic structure through design, production, and maintenance (and the preceding planning phase for system upgrades). This structure is the "repository". To create and provide value to customers on an ongoing basis, the form that a new system or service should take must be clearly explained and consensus with the customer should be obtained as often as necessary. The goal here is to expand the relationship and develop a good partnership.

The second feature is the reorganization of technology, the source of value for customers. The greatest strength of Fujitsu in the solutions business is its ability to assemble in a flexible manner all of the technical capabilities of its field, service-provision, common-technology, product, and quality-control departments. On the other hand, it has been suggested that those technical capabilities might be weakening in the face of a growing trend toward open systems. At present, however, asking whether those capabilities have been weakened or not is beside the point. What is important now is to sharpen technical capabilities as a forward-looking measure toward the new era of Cloud computing. Here, the formation of a technology system that combines previously developed technologies with new technologies and the training of personnel to put this system to good use is defined as Human Resources Innovation. In combination with the existing SE Work Style Innovation initiative (which pursues ongoing improvements as well as reforms in behavior and processes), the aim of Human Resources Innovation is to construct a mechanism for maximizing value and improving quality.

3.1 Design, Production, and Maintenance Innovation initiatives in the second stage

To promote consistency in the Design, Production, and Maintenance Innovation initiatives, the second stage (scheduled to run over the next three years) will feature the following measures.

3.1.1 Repository-based system construction and maintenance

"Traceability" is an important theme in system design, production, and maintenance. Traditionally, much human labor has been required to ensure that defined requirements are designed, implemented, and tested without inconsistencies in a manner that is neither excessive nor insufficient. In addition, many people have been needed to analyze and test the range of effects when an existing system has been expanded. Having to depend on so many people in this way might allow results that reflect personal differences and cannot help but increase the time required to complete the tasks. In short, this dependence on human labor acts as an impediment to efforts to improve quality and shorten the development period.

The second stage of these initiatives aims to smooth out the traceability process by converting all design information, beginning with the requirements definition, into a repository and to apply that repository throughout design, production, and maintenance activities (**Figure 2**). The use of a repository came into practice in the conventional application framework for the purpose of automating code generation and code synthesis. In a similar manner, an independent and practical repository system became used for requirements definition information and basic design information. The plan now is to link these two systems and set up a repository-based mechanism for use throughout the system's lifecycle. Needless to say, the construction, operation, and management of a repository will depend on project characteristics (number of project members, etc.) and development technique (rapid application development, waterfall development, etc.)

An SE can get a computer to extract and process repository-based information, such as information for checking the traceability of requirements, information for design reviews, and information for test variations, and can use this information to set up a mechanism devoted entirely to decision making. This approach helps to minimize personal differences in results and shorten development time, enabling the provision of a highly consistent solution.

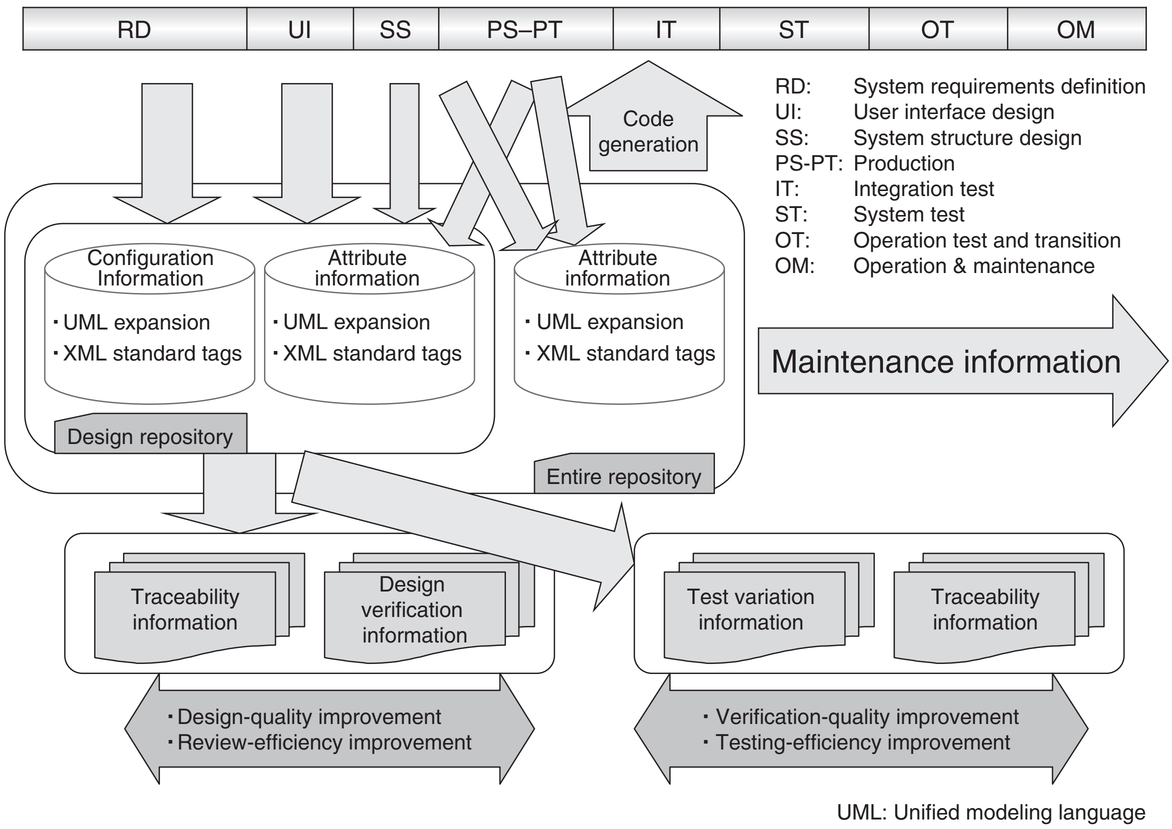

Figure 2
Repository of design information.

3.1.2 Standardization of repository information

Standardization plays an important role in facilitating the exchange and sharing of repository information among tools that extract useful information for engineers who need to perform design reviews, operation tests, surveys on the effects of upgrading specifications, etc. The solutions services field is highly diverse in terms of business scale, types of target businesses, and work processes. All-purpose tools that are claimed to be adept at handling such diversity are apt to be massive and slow and to have inadequate usability. This field also appears to have a hard time keeping up with advances in man-machine interface technology. Thus, a much more realistic approach is to create a family of easy-to-use specialized tools corresponding to various types of usage organizations and project characteristics and to use the tool that best fits the current need.

In the second stage of the four innovation initiatives, Fujitsu will work to set extensible markup language (XML) standard tags for repository information and create a platform for exchanging and sharing information between tools (in conformance with standards like the Meta-Object Facility[3]). This platform will be combined with standard tool sets that include functions needed by a system integrator.

3.1.3 Pursuing completeness in business rules

In recent years, the importance of quality control in upstream processes has become generally recognized and requirements definition guidelines and diagnostic methods for user interface designs have come to be established. At present, efforts are also being made to develop ways of checking the validity of requirements and set up user interface design guidelines. Nevertheless, determining the completeness of business rules and understanding variations in business specifications in particular business areas still depend heavily on the skills of individuals knowledgeable about those areas. As a result, personal differences can have a significant effect on review and test quality, presenting an obstacle to quality improvement. In areas close to the source-code level, there is much test-driven development[4] as well as many open-source products based on the test-driven approach. At the upstream level, certain approaches to testing like the W-model exist, but they have not yet become established methodologies.

In the second stage, business-rule completeness and variations in specifications will be pursued in requirements definition and basic design. Documentation in this regard will be provided and methods for applying business-rule completeness and specification variations in tests will be established. They will also be pursued in the border regions between business design and basic design (such as business-processing system design, performance design, reliability design, extendibility design, and business-operations design) and documentation will be provided.

On the basis of their extensive experience, Fujitsu SEs have identified the following design paradigms as being beneficial in terms of implementation and testing. These paradigms differ in what kind of data is the focus of design.

1) Data model

This is a conventional design method focusing on relationships among data items and on static relationships among data relationships (application architecture modeling and business rules modeling).[5] It can be used to design a variety of business systems such as production management in manufacturing.

2) State transition

This method designs a set of state-transition matrices focusing on the states of multiple resource object groups and triggers that cause those states to make transitions. (Here, all fields of all matrices are the targets of testing.) Given that the results of operating facilities in facilities-based industries (such as telecommunications companies and energy companies) equate to services, the fact that services connect directly with customers is used in the design of core business systems.

3) Interface schema

This method focuses on groups of data items that cross business-function groups and designs interface schema related to primary data groups and their variation. (In the days of the general-purpose mainframe computer, this was called "telegram design". All combinations of primary data items in an interface schema are the targets of testing.) The interface schema method can be used to design business systems in which data that has been input is passed from one back-office task to another, as in core banking operations and sales-management operations in distribution.

A practical approach in the design of actual business systems is to apply a hybrid design that combines these three design paradigms in some way in accordance with the characteristics of the business in question.

In many business systems in various business areas, the primary conditions that govern business rules and variations in business specifications are well understood. Furthermore, these governing conditions can often be organized in a hierarchical manner. Thus, even as an organizing method that makes use of empirical knowledge, such a method can be used to determine completeness in a sufficiently practical range and to provide documentation. At the same time, by converting such information into a design repository, Fujitsu is pursuing computer-supported completeness in business rules, which should contribute to improvements in review quality and test quality at each of the stages of design, production, and maintenance.

3.1.4 Standardization of management information

As stated above, the solutions services field is quite diverse in terms of business scale, business types, and work processes. In a similar way, project management can take various forms, and project-support tools tailored to the circumstances of individual organizations have come to be used. However, there are hardly any adequate mechanisms for exchanging and sharing management information among these tools.

Thus, another objective of the second stage is to standardize project-management items that have a high degree of universality, to decide on XML standard tags, and to set up a mechanism for exchanging and sharing management information among various types of tools (**Figure 3**).

At present, study groups such as Project Benchmarking and working groups such as WG10 under subcommittee SC7 of ISO/IEC JTC1 have begun working on international standards for management information, and in Japan, studies on advanced software metrics have begun under the guidance of the Ministry of Economy, Trade and Industry (METI). Fujitsu as well will promote standardization while keeping a close eye on these trends. The idea of a project-management dashboard has also been proposed recently, and activities that involve alliances with other companies are thought to be important.

The Function Scale method[6),7)] is also being promoted to complement the Function Point method with the aim of improving the accuracy of estimations for complicated business logic and making estimations at the time of system upgrading.

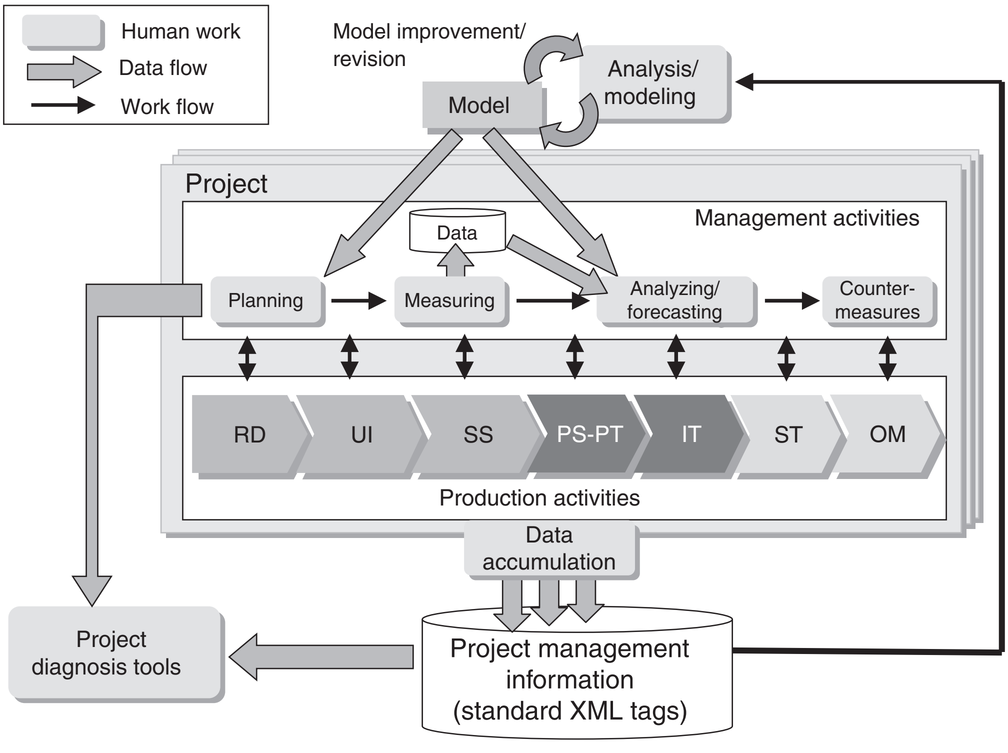

Figure 3
Standardization of project management information.

It must also be pointed out that data associated with software quality and scale estimations/measurements rarely falls on a Gaussian distribution. Its distributions are exceptionally broad compared with hardware, and accuracy is insufficient.[8] Engineering methods for statistically handling such non-Gaussian distributions and data with a large variation are now being improved. The plan is to progressively provide management tools that can be of practical use.

3.2 Human Resources Innovation initiative

In the training and development of SEs who support the solutions business, Fujitsu assigns roles corresponding to the various processes and fields making up a system lifecycle. For example, there are consultants in charge of upstream issues, project managers in charge of development projects, and service managers in charge of operations and maintenance, as well as application architects in charge of applications and information technology (IT) architects in charge of the infrastructure. Fujitsu also promotes the training of quality managers and intellectual property architects to protect quality—the lifeline of business—and intellectual property rights. Changes in the solutions business, however, occur rapidly, with one change quickly followed by another. These include changes in development format (from a new development starting from scratch to the upgrading of an existing system), a shorten, faster development cycle, and changes in servicing (with the aim of leveling and decreasing the cost burden).

To provide leadership in such a rapidly changing environment, each SE must undergo a personal transformation. To this end, basic skills must be redefined (including the redefinition of basic business abilities, which provide a foundation for developing technical capabilities) and the training system must be rebuilt. In the areas of system development and operation, the Fujitsu Group has a massive amount of technology cultivated over many years and an insatiable desire for new technology. With this in mind, the Human Resources Innovation initiative aims to equip all SEs in the Fujitsu Group with the ability to extract this knowledge at any time and to establish a support system to that end. In relation to this initiative, the finishing point of SE Work Style Innovation will be the creation of a process that bundles together various professional abilities to extract maximum performance.

4. Conclusion

The five innovation initiatives, including Human Resources Innovation, are not a final objective but rather a stage in the construction of a new mechanism for achieving sustainable growth in the Fujitsu Group. On completion of this mechanism, the Design, Production (+ experience), and Maintenance Innovation initiatives will be integrated and consolidated into a system (of knowledge) for providing value to customers, and the SE Work Style and Human Resources Innovation initiatives will lead to the development of evolved SEs (next-generation SEs) skilled in using that knowledge. Fujitsu will work to shorten the cycle time of the five innovation initiatives toward a structure in which knowledge and human resources are synchronized to create value continuously and sustain growth.

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