

From *Sashimi* to *Zen-in* : The Evolution of Concurrent Engineering at Fuji Xerox

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Abstract: This case study examines the evolution of R&D knowledge management at Japan's business equipment maker Fuji Xerox, from the sashimi system, a Japanese origin of concurrent engineering, to its successor Zen-in system, which is composed mainly of a real high-tech discussion room equipped with databases that provide technical information and two 70-inch displays that shows virtual but real-size, three-dimensional graphic models. We found that Fuji Xerox has chosen the "hybridization strategy" that mixes human-based and IT-based knowledge-sharing techniques. We also argue that concurrent engineering provides not only efficiency benefits but also positive effects on group and organizational creativity. Finally we present a conceptual framework of "how concurrent engineering works;" i.e., uncertainty and diversity necessitate concurrency which produces such benefits as efficiency and creativity, and which in turn realizes product integrity.

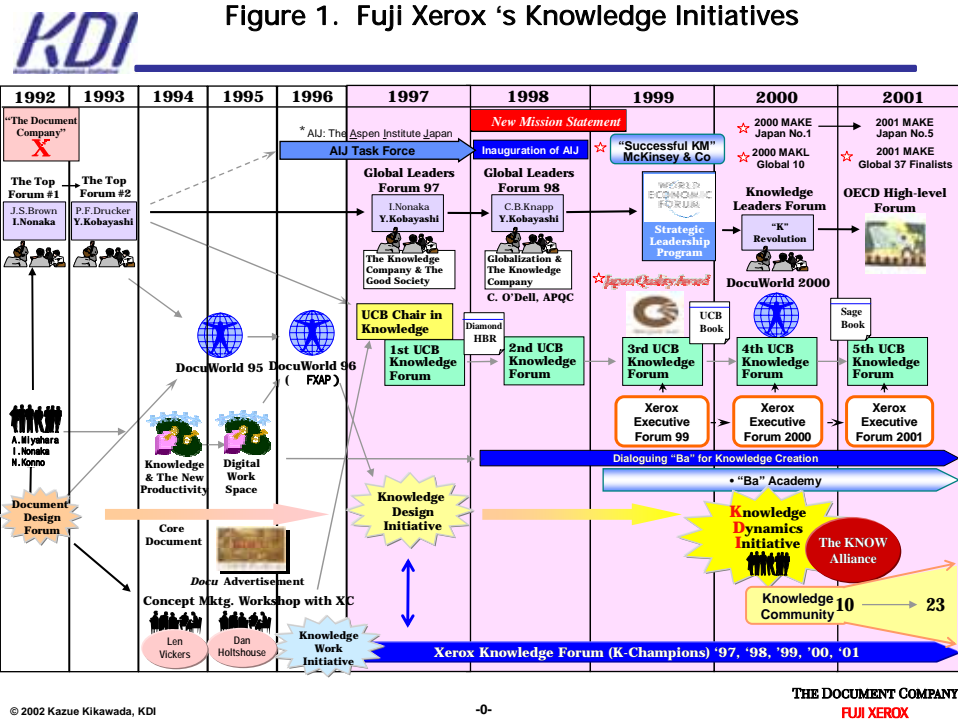
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Introduction

To survive in today's fierce, knowledge-based competition, manufacturing companies should face the challenge of enhancing not only R&D efficiency but also group and organizational creativity, thereby introducing more innovative value-added products and/or services in a shorter lead time. To that end, knowledge-creating companies have developed many R&D practices. One of them is concurrent engineering or "the systematic approach to the integrated, concurrent design of products and related processes, including manufacturing and support." [1] Thus far, however, the literature on concurrent engineering has focused on efficiency but failed to discuss its effects on creativity. [2] We need to examine what effects concurrent engineering has on group and organizational creativity and knowledge creation through its cross-functional, collaborative activities among people of different knowledge domains.

This paper looks back at the history of R&D knowledge management in a Japanese leading business equipment maker Fuji Xerox Co., Ltd., focusing especially on its so-called "*sashimi* system," a Japanese origin of concurrent engineering, and its successor as an R&D knowledge management system called "*Zen-in*" (*zen-in* means everyone), thereby eliciting theoretical and managerial implications of R&D knowledge management for organizational creativity.

Fuji Xerox was established in 1962 as a joint venture between Fuji Photo Film Co., Ltd. and Rank Xerox Limited, a British subsidiary of Xerox Corporation of the United States. Since then, the company has fiercely competed with such rival makers as Ricoh, Canon, Sharp, and Mita (now Kyocera Mita) in the small and medium-sized copier markets. In 1992, Fuji Xerox and its parent company Xerox Corporation declared together that they would become “The Document Company,” viewing documents as a medium that conveys information and knowledge among people and motivates their actions. Thus, Fuji Xerox had noticed the importance of knowledge before the knowledge management movement started worldwide in the mid 1990s (Nomura, 2001). And now, it defines its mission as “Build an Environment for the Creation and Effective Utilization of Knowledge.”[3] As this mission statement shows, Fuji Xerox has emphasized the building of knowledge environment, recognizing the creation aspect of knowledge management, unlike the widely-accepted but somewhat misleading definition of knowledge management as mere utilization of existing knowledge. Due to such a negative connotation of “management” as “control,” moreover, the company prefers the word “initiative” to “management,” thus calling its knowledge-related projects “Knowledge Initiatives” (see Figure 1 for an overview of Fuji Xerox’s Knowledge Initiatives until 2001).



It should be noted that Fuji Xerox had introduced the two R&D or knowledge-creating practices before the knowledge management movement gathered momentum in the late 1990s. And truly, through R&D, all companies have always created knowledge and embodied it into new products, new services, and/or new management systems. Thus, knowledge creation as part of knowledge management has been, in effect, practiced long before the advent of the buzz word. Therefore, knowledge management should mean that any organizations do two things more intentionally and systematically: (1) create new knowledge so as to realize their visions; and (2) share and utilize

existing knowledge far more efficiently and effectively through information technology (IT) and face-to-face meetings so as to facilitate the knowledge-creating process. The former is relevant to creativity whereas the latter is to efficiency.

Japan's manufacturing prowess

In the mid 1980s, Japan appeared to be an invincible economic juggernaut and Japanese automobile and electronics manufacturers in particular had gained increasingly higher shares of global markets respectively. Business scholars and practitioners were asking such questions as “What are the key factors to the Japanese manufacturers’ remarkable successes?” and “What are the sources of their competitive advantage?” The *sashimi* system seems to give answers to these questions. Before moving on to that topic, however, more general findings about features of the Japanese manufacturers’ product development process are summarized below.

A great amount of literature has discussed what sources of competitive advantage Japanese manufacturers have. Thus far, there has been one consensual view that the product development system and the quality control movement are their major sources of competitive advantage. The following features of Japanese manufacturers’ product development process were found by, among others, Imai, Nonaka and Takeuchi (1985); Takeuchi and Nonaka (1986); Clark and Fujimoto (1990); Womack, Jones and Roos (1990); and Clark and Fujimoto (1991):

- the cross-functional project team that facilitates the sharing and cross-fertilization of information among team members from different functional departments within a company and with suppliers as well;
- considerable autonomy granted onto the cross-functional team and subtle control through strategically ambiguous goals from the top, thereby helping self-organize the development process;
- overlapped phases of the development process, thereby reducing coordination costs and the lead time while enhancing “product integrity,” i.e., internal consistency among a product’s parts, components and functions, and external consistency between its performance and customers’ expectations;
- “shared division of labor,” where each team member feels responsible for any aspect of the project, thus assuring product integrity;
- “frontloading” through which all project members participate into the earlier phases of the development process and find as many problems as possible therein;
- extensive interaction and communication among team members as well as with suppliers, thereby increasing speed, flexibility, and product integrity;
- simultaneous development of new components, product prototypes, and production-line specifications, thereby reducing the lead time and increasing product integrity; and
- “integrative leadership” exercised by so-called “heavy-weight project managers” who are characterized by effective coordination within the cross-functional project team (i.e., high internal integration) and an effective matching of the product to customer expectations (i.e., high external integration).

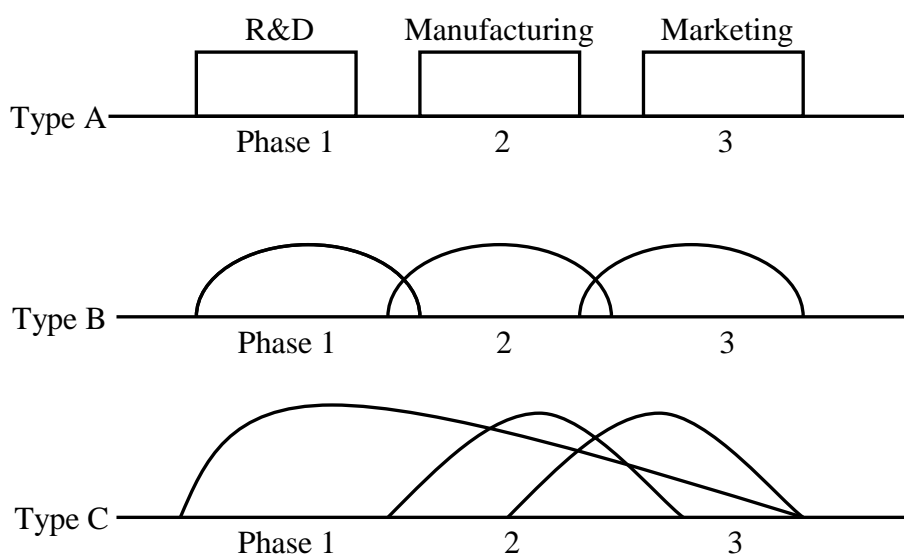
Also, Imai, Nonaka and Takeuchi (1985) summarized features of the overlapping approach (e.g., the *sashimi* system) in particular as follows:

- sharing of responsibility is accepted as the team embarks on a risk-taking mission;
- cohesion is promoted as team members face some challenging goals. The broad nature of the goals also helps to alleviate detailed differences;
- ambiguity is tolerated, given the diverse backgrounds of the team;
- overspecification is avoided, since it may impair creativity;
- sharing of information is encouraged so as to become better acquainted with realities of the market; and
- decision making is intentionally delayed to extract as much up-to-date information as possible from the marketplace and technical communities.

***Sashimi* System**

The term “*sashimi* system” was first introduced to Western business scholars and practitioners at the 75th Anniversary Colloquium of the Harvard Business School in 1984. In retrospect, it was then that the project for *The Knowledge-Creating Company*, a classic in the field of knowledge management, started out (Nonaka and Takeuchi, 1995, p.vii). The paper presented at the Colloquium was later published as the two articles, i.e., Imai, Nonaka, and Takeuchi (1985) in the Colloquium proceedings and Takeuchi and Nonaka (1986) in the *Harvard Business Review*. Since the latter article memorably entitled as “The new new product development game” was published in the world’s most prestigious business management journal, it has strongly affected the then-linear thinking of business scholars and practitioners worldwide.

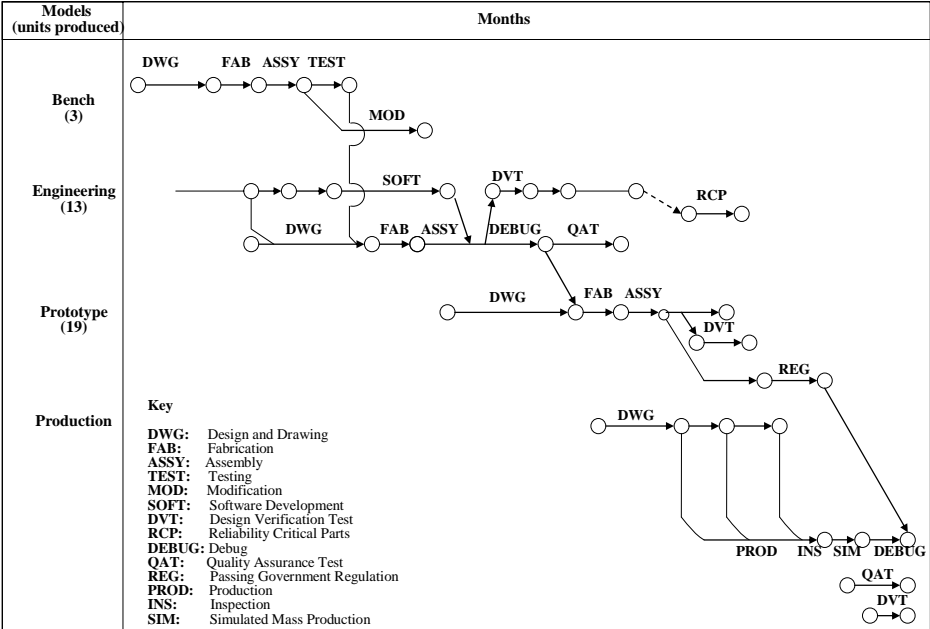
Figure 2. Sequential vs. Overlapping Approaches



Source: Adapted from Imai, Nonaka and Takeuchi (1985), p.543.

The *sashimi* system was built in the mid 1970s when Fuji Xerox developed a medium-sized, innovative copier FX-3500 that captured 60% shares of relevant domestic market. The copier maker evolved the non-linear, four-phase *sashimi* system from the linear, sequential, six-phase PPP (Phased Program Planning) system it had inherited from its parent Xerox Corporation. The traditional, linear, sequential system is depicted as Type A in Figure 2 in a simplified way. Using a sports metaphor, Nonaka and Takeuchi (1986) called the traditional system the “relay approach,” because each phase of the development process is clearly separated and the baton is passed from one group to another. Likewise, Nonaka and Takeuchi (1995) called the third approach (shown as Type C in Figure 2) the “rugby approach,” in which the overlap extends across several phases and team members “run together, pass the ball left and right, and reach the goal as a united body”(p.78). The *sashimi* system was named so because its overlapping phases look like raw fish slices overlapping one another. The overlap occurs only at the border of adjacent phases (see Type B in Figure 2 and Figure 3).

Figure 3. Sashimi System



Source: Imai, Nonaka and Takeuchi (1985), p.544.

The *sashimi* system required extensive interaction and communication not only among project members from different functional sections but also with engineers from parts suppliers. At Fuji Xerox, for example, the cross-functional project team that developed the FX-3500 copier was composed of members with the following functional backgrounds: 5 from R&D, 4 from production, 1 from sales, 4 from planning, 1 from services, 1 from quality control, and 1 from others. Furthermore, they invited suppliers to join the project team at the very start. Each side regularly visited the other’s plants and shared information and knowledge at all times, thereby increasing speed and flexibility of development. Thus, the lead time was shortened from 38 months of an earlier model to 29 months of FX-3500. In addition to such merits as greater speed and flexibility, the overlapping approach also enhances shared responsibility and cooperation, stimulates involvement and commitment, encourages initiative taking, fosters more strategic viewpoint of a generalist, sharpens a problem-solving

orientation, develops diversified skills, and heightens sensitivity toward market conditions (Imai, Nonaka and Takeuchi, 1985; Takeuchi and Nonaka, 1986).

By the mid 1980s, the overlapping approach established itself well into the development process at Fuji Xerox. As the business process in general got digitized, so did the product development process that introduced a CAD (or Computer-Aided-Design) system. In the early 1990s, the company built a database to store articulated design know-how. The information system was a flop, because it was UNIX-based and therefore unpopular among engineers who had been PC users. Only 100 engineers regularly visited the database, the number of know-how registration continued to be less than 100 per year, and the number of registered know-how reached a plateau of about 1,000 by the mid 1990s (Nakayama, 1997; Kobayashi and Morishima, 2000).

Zen-in System

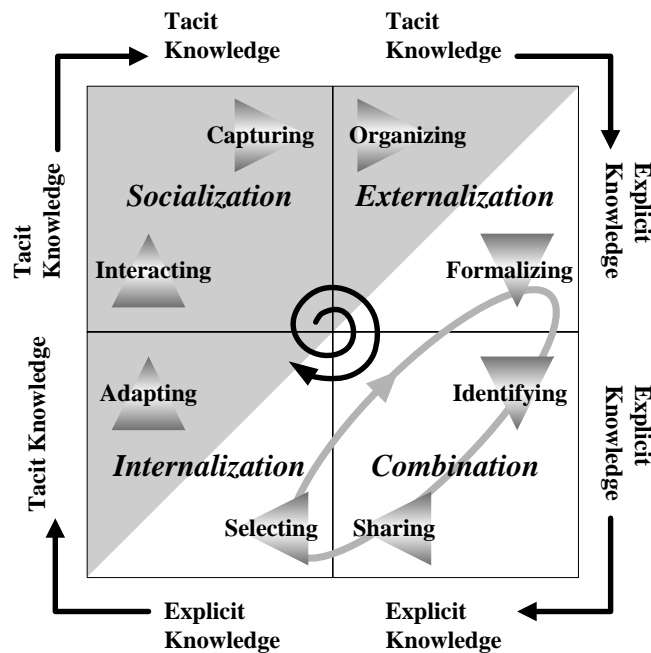
In January 1995, Fuji Xerox embarked upon a corporate-wide program that aimed to change the entire process of product development. Shin-ichi Tsuda was appointed as the first manager responsible for the challenging program. He had 25-year experience of developing copiers. At that time, copiers were getting colorized, digitized, networked, and multi-functionalized, which requires integration of diverse domains of knowledge about coloring chemicals, semiconductors, software programs, customer needs, and so on. Tsuda said, “the key to knowledge integration is knowing who knows what and how much.” He also thought that gathering many experts together and finding problems as early as possible in the development process would help shorten the lead time. For him, experts include all relevant professionals; that is, not only design engineers in different development phases but also product planners, production engineers, quality control specialists, marketing personnel, field services engineers, and suppliers’ engineers. By gathering together such diverse expertise from different knowledge domains, he intended to change not only the development system but also engineers’ mindset (Kobayashi and Morishima 2000).

To attain these two goals, he devised an idea of the *Zen-in* Design Room, where *zen-in* or everyone participating into a development project comes together to discuss any problems over virtual, real-size, three-dimensional graphic models in the earlier phases of the development process. The room was to be wired to an intranet-based information-sharing system called Z-EIS (*Zen-in* Engineering Information System) still in the planning stage at that time. Z-EIS was planned to feature a three-dimensional CAD system and hundreds of databases to store articulated know-how and supply it to engineers of such diverse fields as mechanical, electric, electronic, software, production, reliability engineering, etc.

In the mid 1990s, the most nagging problem for the company’s R&D managers was a prolonged lead time due to design changes in the last phase of development. They decided to solve the problem but found it difficult to check defective designs in the earlier phases. Two-dimensional blueprints could not provide enough information to review designs of copiers that were made of more than 2,000 parts. Engineers responsible for the last phase had to wait for a prototype. To solve the problem, therefore, designers and engineers of the entire development process began *interacting* with one another to have

discussions in search of solutions. They soon noticed that know-how or tacit on-the-site knowledge of designers and engineers is important but becomes explicit only in front of prototypes and/or on the site. Thus, they started visiting each site of the development phase, trying to *capture* tacit on-the-site knowledge. It was the socialization of the SECI model developed by Professor Nonaka (see Figure 4).

Figure 4. Elaborated SECI Model at Fuji Xerox

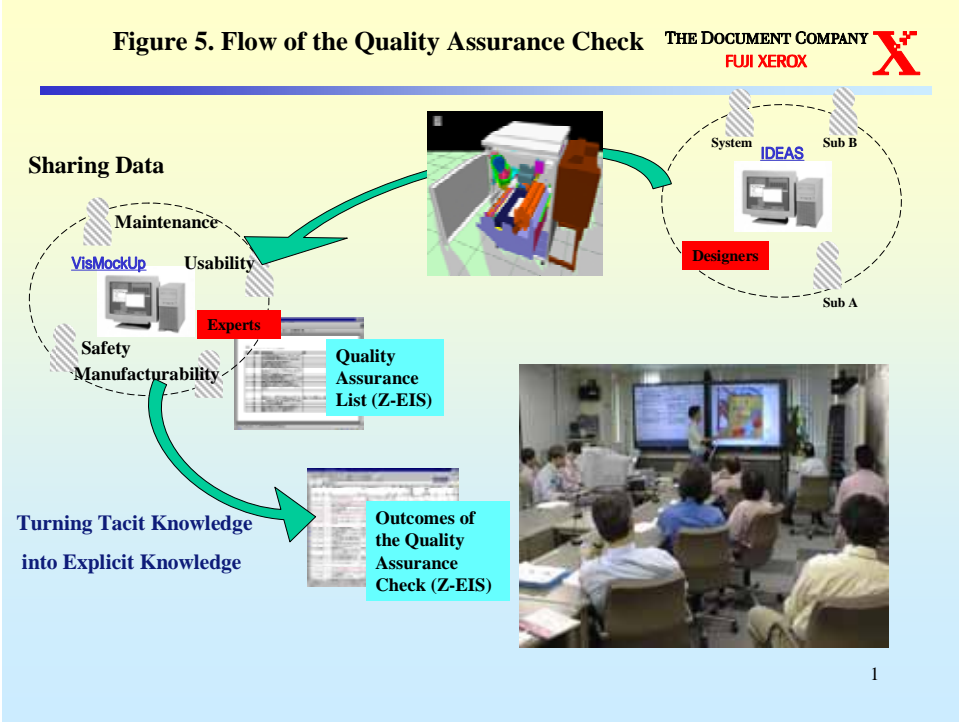


Source : Adapted from Nomura and Kametsu (1999) , p.64

The first *Zen-in* Design Room was built in 1996 at the Corporate Research Lab of the Ebina Plant in Kanagawa Prefecture. It is a mix of a real *ba* (or space)[4] for face-to-face discussions and a virtual *ba* or cyberspace for cross-fertilizing information or knowledge creation, where designers and engineers come together from every phase of the development process to have face-to-face discussions over virtual but real-size, three-dimensional graphic models on 70-inch screens of the CAD system (see Figure 5). The “*Zen-in* Design” or “Design by Everyone” means that every designer or engineer should participate in the whole development process by making comments and/or suggestions for better designs while taking responsibility in his or her own area. Yet, a problem remained: that is, how to *organize* the articulated knowledge, i.e., formerly tacit on-the-site know-how that was *captured* or socialized through the mutual visits by engineers. The solution for this problem is Z-EIS, into which engineers articulate and input (i.e., *formalize*) their on-the-site know-how. This is the externalization of the SECI model (see Figure 4).

Because not every piece of the *formalized* knowledge is useful enough to be *shared* among all engineers, middle managers of each development phase had to *identify* only usable items to be officially registered on the Z-EIS databases. Thus, quality of input data was assured. Such a selective

registration has become a success factor to IT-based knowledge sharing. In addition to the articulated on-the-site knowledge, three-dimensional graphic models, parts specifications, market data, patents information, and product management data have been input into the ever-increasing number of databases of Z-EIS. This is the combination of the SECI model (see Figure 4).



As with all knowledge-sharing projects through databases or what Hansen, Nohria, and Tierney (1999) called “codification strategy” [5] for knowledge management, the most difficult problem for Z-EIS was how to increase the number of inputs of know-how. At first, most engineers did not find any merits in registering know-how, a tedious and less rewarding work. In 1996, the registration number reached to 1,500 as Z-EIS became Web-based and therefore much easier to input and the registration campaign along with a reward system (1,000 yen or 8 dollars per one input) started. The incentive does not seem to be effective, though. The company is planning to introduce a system to show the popularity and thereby contribution of any registered know-how, thus stimulating engineers’ pride as an incentive to registration (Noguchi 2001).

For registered items of know-how to become really significant, they must be actually utilized and lead to action. To efficiently and effectively utilize the articulated know-how, therefore, most useful items are *selected* and compiled into the “Quality Assurance List,” that is, new explicit knowledge to be utilized for design reviews. Thus, the explicit knowledge of design and development know-how are utilized and *adapted* on the site, thereby becoming tacit know-how again. This is the internalization of the SECI model (see Figure 4).

The SECI process is not a cycle but a spiral. Therefore, the knowledge-creating process goes on, expanding and entering into socialization again. Designers and engineers with enriched and embodied

tacit knowledge come back to *interact* with one another at the *Zen-in* Design Room, thus socialization again. Nomura and Kametsu (1999) pointed out that the currently prevalent knowledge management practice of sharing and utilizing extant knowledge forms the cycle of actions from *formalizing* to *selecting*, contributing to some increase in efficiency but little in organizational or group creativity. Thus, Fuji Xerox has been practicing an elaborated SECI model (see Figure 4).

Structure and Nature of Z-EIS

Z-EIS is composed of three menus called “news,” “forum,” and “cockpit,” respectively. The “cockpit” supplies technical information through 7 channels, each of which is specialized in different type of information as follows:

Channel 1: In-house technical information such as design know-how;

Channel 2: Outside technical information such as patents or electronic catalogs;

Channel 3: Software packages as computational tools for design;

Channel 4: Simulation software including such analysis tools as CAE;

Channel 5: Workflow management information;

Channel 6: Utilities information such as telephone numbers; and

Channel 7: CAD data such as digital blueprints.

Most important is channel 1, which aims to realize the very goal of Z-EIS, i.e., provision of every kind of information necessary for product development. It is divided into 6 databases for patents, technology, design, production, market, and “general.” Furthermore, the “design” database is subdivided into more specific categories about such topics as design know-how, safety, and environment. Thus, as of late 2001, the total number of databases is 300 and about 6,300 pieces of articulated know-how (or explicit knowledge) are stored to be shared and utilized for 500 designers and 4,100 engineers, and about 300,000 inquiries come to Z-EIS every month (Nakayama, 1997; Noguchi, 2001).

The most-frequented category is “design know-how,” which stores solutions for past troubles or failures in the design process. The digitized solutions in text and/or image can be retrieved through key-word, full-text, or hyper searching. Moreover, Z-EIS provides information about troubles on production lines and the marketplace (Kobayashi and Morishima 2000). According to Teece (1997), such “negative knowledge” helps engineers avoid blind alleys in research and steer resource allocation into more promising avenues.

Regarding the nature of Z-EIS, Tsuda thinks that it may provide engineers with documents as explicit knowledge, but more significantly it is a “trigger” that helps them see one another in person, thereby sharing tacit knowledge. He says:

I am not saying Web-based knowledge sharing doesn't work, but more significant is that Z-EIS becomes a trigger for knowledge sharing. You can rarely find the very information you want in relevant documents through Z-EIS. But you can refer to authors of the

documents and ask for more information from them. Z-EIS is a *ba* that gives you such a chance (quoted by Kobayashi and Morishima, 2000, p.156).

Conclusions

Owing to the “*Zen-in System*,” the development lead time has been shortened from two years to one year. With extensive and intensive discussions over virtual prototypes, moreover, Fuji Xerox could reduce the number of real prototypes from three to one, each of which costs hundreds million yen (or million dollars), thus cutting the development costs as well. These are the “efficiency effects” from the concurrent engineering as practiced in the “*Zen-in System*” at Fuji Xerox. As evidence for a creation effect of the *Zen-in* system, J. D. Power Asia Pacific announced in its 2003 customer satisfaction ranking for color multifunctional systems that Fuji Xerox was ranked first with a decisive lead, scoring the best for product themselves, including their functions such as printers and scanners, but also sales and services. This means that through the *Zen-in* system Fuji Xerox has produced the best multifunctional products which need more creativity to realize the multi-functionality and the highest customer satisfaction [6].

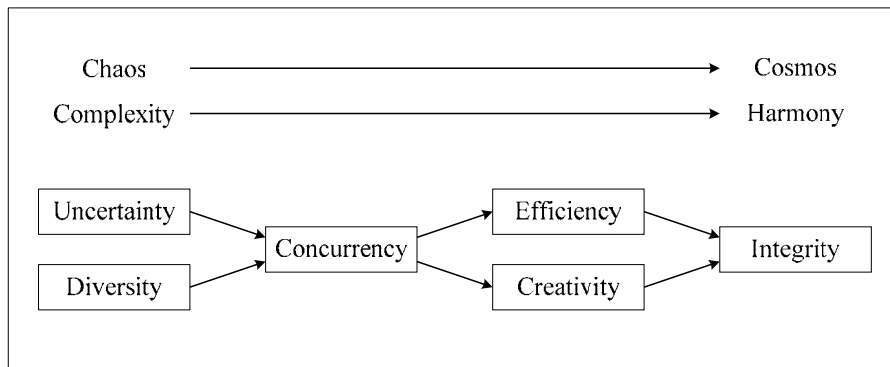
Regarding creativity effects of concurrent engineering, cross-fertilization of information, that is, knowledge creation is driven by its cross-functional, simultaneous, collaborative activities among professionals from many different knowledge domains. Given such diverse backgrounds of the cross-functional team and strategically ambiguous goals from the top, uncertainty should be tolerated and overspecification and too-early specification should be avoided in order not to impair creativity. It is out of these internal uncertainty and diversity that concurrent engineering has emerged. Also, out of such uncertain and diverse external factors as unpredictable market conditions (e.g., volatile consumer preferences) and unforeseeable technological advances, has emerged the R&D practice, a “creative chaos” [7] in itself (see Figure 6).

We can define organizational (or group) creativity as an organization’s (or a group’s) ability to integrate different domains of knowledge and the two different types of knowledge, i.e., tacit knowledge and explicit knowledge, thereby producing innovations continuously. Concurrent engineering itself is such an innovation and can be depicted as an organization’s series of parallel actions to change such chaotic and complex conditions into a product that has integrity (i.e., a harmonious cosmos) through efficiency and creativity effects that its concurrency produces. Product integrity may have economic, aesthetic and moral dimensions, each of which satisfies consumers’ expectations, i.e., a reasonable price, taste, and environmental-friendliness, respectively.

Another implication from this case study is that concurrent engineering needs social capital, i.e., trust-based know-who networks, or knowledge in itself, as suggested by Tsuda’s comment: “the key to knowledge integration is knowing who knows what and how much.” Cross-functional and inter-organizational nature of concurrent engineering (the latter is the relationship with suppliers or universities) requires extensive networking when the project team starts and while it proceeds as well. Such trust-based know-who networks can convey tacit knowledge, while IT networks such as Z-EIS can carry explicit information. Note that IT networks give mere “accessibility” to such explicit

information and do not guarantee the “sharing” of explicit information or explicit knowledge (i.e., a body of systemized information). They should always be complemented by human networks, as explicit knowledge is complemented by tacit knowledge.

Figure 6. Factors to Concurrent Engineering



As for managerial implications, this case study provides strong evidence against Hansen, Nohria, and Tierney (1999)’s argument that we have to choose either the IT-based “codification strategy” or the human-based “personalization strategy.” As one of the present authors argued elsewhere (Umemoto, 2002), the typology is a false dichotomy; knowledge management should pursue both strategies at the same time, because the two strategies, and explicit and tacit knowledge each focuses on, are complementary and equally important. The *Zen-in* Design Room, as originally conceived by Tsuda, seems to represent the “personalization strategy,” so does Z-EIS the “codification strategy” (needless to say, these terms did not exist in 1996 and therefore Fuji Xerox did not use them). In reality, however, it is a mixed *ba* of face-to-face meetings (i.e., real *ba*) and on-line databases and discussion forums (i.e., virtual *ba*), thus suggesting the “hybridization strategy” as the right way for knowledge management and concurrent engineering.

Notes

1. This is an often-cited definition by the Institute of Defense Analyses and can be found at the Concurrent Engineering Web Page of the College of Computing at the Georgia Institute of Technology (2003): (http://www.cc.gatech.edu/computing/SW_Eng/people/Phd/ce.html). This definition continues as follows: “This approach is intended to cause the developers to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.”
2. Machado (2003) is an only exception we have found so far.
3. (<http://www.fujixerox.co.jp/eng/mission/index.html>).
4. For the concept of *ba*, see Nonaka and Konno (1998).
5. Hansen, Nohria, and Tierney (1999) argued that there are two types of knowledge management strategy, i.e., “codification strategy” in which “knowledge is carefully codified and stored in databases, where it can be accessed and used easily by anyone in the company,” and “personalization strategy” in which “knowledge is closely tied to the person who developed it and is shared mainly through direct person-to-person contacts” (p.107). They also argued that: (1) the

choice between the two is a central issue for KM; (2) trying to pursue both at the same time may harm corporate performance; and (3) one should be adopted as main and the other as complementary.

6. (http://www.jdpower.co.jp/index_e.html).

7. For the concept of “creative chaos,” see Nonaka and Takeuchi (1995), pp.78-80. It can be called “organized chaos,” too.

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