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Abstract

The collaboration issues on research and development (R&D) projects are getting critical. Shorten time-to-market (TTM) of new product is crucial competency of high-tech industries. However, lacks of post-project review, real-time communication and information sharing make barriers to reduce TTM. This would lead to downcast competition in the globalization. In this research, a concurrent knowledge learning (CKL) model is proposed to enhance R&D project collaboration. With the CKL model, R&D collaboration could be improved via the concurrent knowledge reusability and the collaboration mechanism among partners.

1. Introduction

Shorten the time to market (TTM) is the central of R&D projects management. While R&D projects generate artifacts in various forms of knowledge, there should be an efficient knowledge management mechanism so that the R&D projects could be executed efficiently and the TTM could be improved. This knowledge management mechanism should be encouraged by integrating with project management. Through the knowledge learning process, organization can keep continuous improving in the efficiency of R&D projects and shortening TTM [9]. However, most organizations lack post-project review processes. And projects are closed before reviewing the causes of their failures and successes [10]. This can discontinue the organization learning process and restrain the improving of R&D efficiency. The lack of post-project review results in learning discontinuity, knowledge disintegration, and makes barriers to shorten the TTM.
Concurrent Engineering (CE) is one of the remedy to shorten TTM. CE was introduced in the late of 1980s to improve collaboration efficiency with team, which highlighted the synchronism of relevant sequential activities of new product development [14]. Also, CE was discussed to be consolidated with process modeling and analyzing. Process modeling made the new R&D projects process to be easily analyzed, and synchronized with the concurrent engineering [1]. With such a concurrent development process, the TTM of R&D projects could be improved for the enhancement of collaboration and concurrent capability.

2. Barriers of R&D Collaboration

R&D projects always have more complexity, difficulties and dynamics [12]. All of them make a higher risk to R&D projects. Nowadays, many companies try to utilize collaboration in R&D projects to share information. However, collaboration itself raises some issues. After literature review, the barriers of R&D collaboration are categorized into two main categories: the information sharing and the organization learning. The barriers of R&D collaboration are summarized in figure 1.

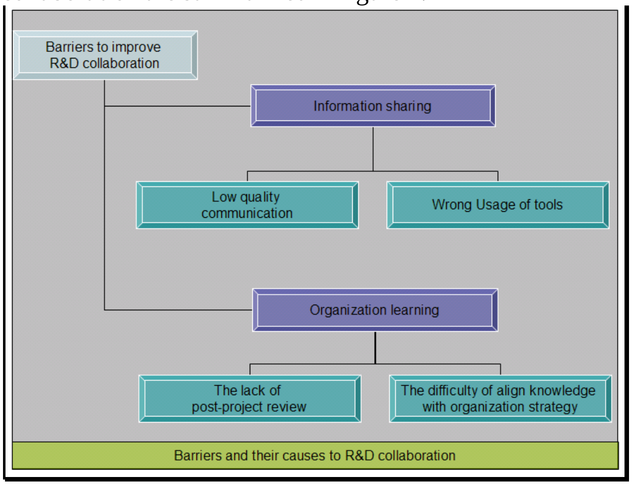

Figure 1: Barriers of R&D collaboration

With the difficulty of establishing and maintaining the communications, R&D project teams are encountering low quality communication. Most communication problem arises from cultural differences as well as roles and responsibility problems. Such problems could lead to downcast efficiency, even mistrust or suspicion [11]. However, information sharing and communication between partners are critical with globalization and collaboration [4]. Wrong usage of groupware or information sharing tools can also limit the learning and innovation in R&D teamwork [3].

Besides, knowledge management has been emphasized for its importance of knowledge reusing and diffusing. Organizations gain knowledge to improve developing process and reduce TTM from the implementation of post-project review [5] [7] [9] [13]. But this is difficult because of the differences in resource, information, specification among projects and the fragmentation of the team by profession or know-how of team members [10]. An "aging work force" and rapid advance in technology even makes it critical for organization to filter knowledge into its core strategy [6].

Collaboration makes it easy for each R&D team unit (an individual or a subgroup) to focus on its core ability. This could lead to the maximized synergy if the quality of collaboration is made certain. In next section the CKL model will be described, by which above barriers could be overcome by the employing of CE and Knowledge Management.

3. Concurrent Knowledge Learning Model

The Concurrent Knowledge Learning (CKL) model integrates two levels of organization learning, with a central concept of concurrent engineering (Figure 2). The infrastructural level, witch is shown in the center of Figure 2, contains one kernel and two shells, the Concurrent Knowledge Engine (CKE) as the kernel, with the Virtual Value Chain (VVC) shell and Knowledge Network shell. R&D project collaboration forms the application level which is based on the infrastructural level and shown as the skirt of the infrastructural level. The CKL model proposes a framework for R&D collaboration to extract and imbibe knowledge through each activity among R&D projects. By this circulating model, artifacts of variety of knowledge are fed back and diffused concurrently to improve the quality and help decision making of each R&D project. Future more, for the R&D project collaboration, the barriers of information sharing and organization learning could be overcome with its abilities of concurrent information sharing and concurrent knowledge learning. Four major components of CKL model are described as follow.

3.1 Concurrent Knowledge Engine

The central concept of CKL model is the Concurrent Knowledge Engine (CKE), which is shown as the kernel of model in Figure 2. CKE stress the parallelism of the two levels. With the CKE, the valuable artifacts which generated from activities among R&D projects can be shared to each others concurrently, rather than the traditionally sequential ways. In other words, in a CKE based environment, the diffusion of knowledge within an organization is no longer passed one by one, but concurrently radiate to every department, every member, even every stage among different R&D projects. This

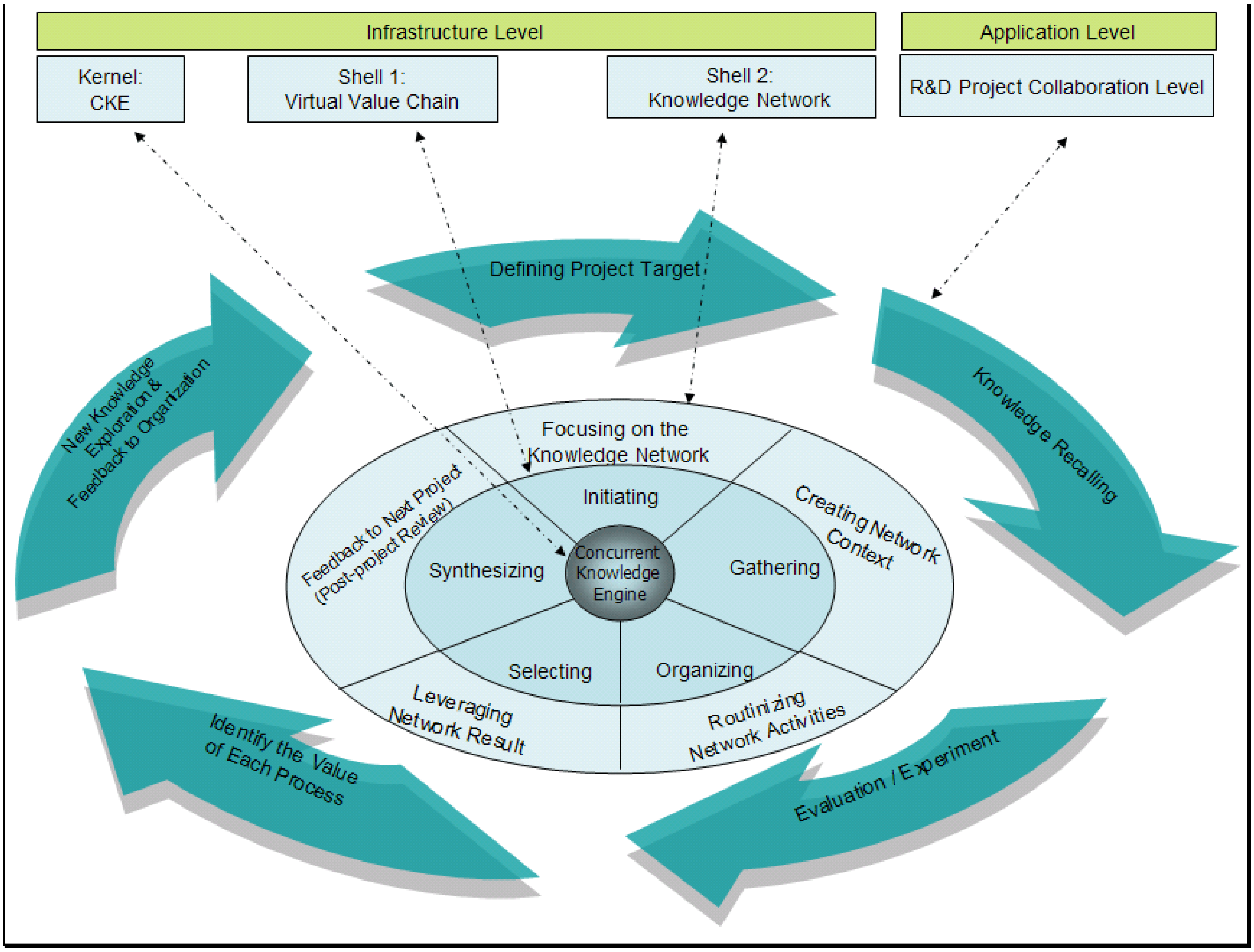

Figure 2: CKL model

could be performed by a centralized knowledge base, which contains knowledge of R&D artifacts and relative value of R&D activities.

3.2 Virtual Value Chain Shell

Virtual value chain was first introduced by Jeffrey F. Rayport and John J. Sviokla in 1994 and described much more specifically in 1995. Five value-adding steps - gathering, organizing, selecting, synthesizing, and distributing - are performed in the virtual value chain (VVC). The value-adding process is fundamentally different from sequential physical value chains. Virtual value chain creates value from extracting information from physical process, organizing the information, selecting and synthesizing valuable ones, finally distributing them into proper destination [8]. The CKE emphasize the concurrent operation of the virtual value adding activities. While each activity adds value to R&D artifacts, the value of new explored knowledge is distributed and shared concurrently to each others.

In CKL model, an initiating stage is added into the VVC shell in order to correspond with the knowledge network shell and R&D collaboration level. In the initiating stage, a new R&D project is getting started and the knowledge network is getting focused. Organization begins to identify related resources and information, including human resource, project specification, even the knowledge fed back by other R&D projects and other tangible and intangible ones. In this stage, value is added onto those information or resources. For example, the configuration of human resource and the project specification are modeled into standard form, making them easier to access and becoming more valuable information during the entire R&D project process. The gathering stage gathers knowledge from organization knowledge base. The knowledge is extracted from activity of every previous R&D projects. By gathering and reusing the knowledge, the value of knowledge is utilized by the on going R&D projects. The organizing stage then organizes the information and the knowledge extracted from organization knowledge base to fit current R&D project. Turning and modifying the knowledge rules are performed in this stage in order to make them more adapted to the situation. Also, knowledge rules are organized and integrated within this stage. In CKL model, the organized knowledge rules are applied to current R&D project, used to select most important and most valuable experiments to be performed. These knowledge rules help R&D team making decision and technology selection and to avoid unnecessary cost, both tangible and intangible, by the support of selecting what activity is need and what is not. In the selection stage, new valuable knowledge rules are selected to be synthesized.

At last stage, the synthesizing, original knowledge and new explored knowledge are compounded and new value is extracted again. These knowledge and value are concurrently fed back to the CKE and diffused through the concurrent environment to other on going R&D project. For example, at the synthesizing stage of project A, the R&D team might find a better way to allocate limited human resource and fed it back to the CKE. And this value-adding knowledge is extracted through the CKE by the team of project B which is just at the initiating stage. So the project manager of project B now can do a better configuration of human resource with the help of the valuable knowledge and experience from project A, as "concurrently" as possible. This is the concurrent collaboration among R&D projects.

The first four stage of VVC shell in CKL model all attempt to extract new knowledge, which adds value to the organization. At the synthesizing stage, original knowledge and new explored knowledge are compounded to extract new value. The knowledge is then concurrently fed back to the CKE and diffused to other R&D project concurrently.

The reason why the distribution stage of VVC is not shown in CKL model is that the distributing of information and knowledge has been implied within the CKE

3.3 Knowledge Network Shell

Four stages for building a knowledge-creating value network are defined in [2]. In CKL model, one new stage is added in order to utilize the knowledge created through the network and to link all others. That is to feedback the new extracted knowledge to next project or is called post-project review [10]. While knowledge rules diffuse to each R&D projects concurrently, the organization is learning from previous R&D project and related knowledge expands. Therefore, the knowledge network shell becomes a spiral expending loop that the knowledge expends and is shared concurrently with each R&D project. Knowledge network shell can be seen as a more practically expended view of the virtual value chain shell in CKL model. Each stage of the knowledge network shell and the relationship with the virtual value chain shell in CKL model are described as follow.

First stage is focusing on the knowledge network. The knowledge network is initiated in this stage and need to be focused to be aligned to the core strategies of the organization. In R&D project case, the network should be highly supported by the organization and be ensured to organization learning level but not only individual level. And the strategy is to shorten TTM. In the second stage, to create the network context, the activity of "gathering" in the virtual value chain shell plays an important role in this stage. Reliable experts are selected to ensure the accuracy and rank the effectiveness of each knowledge rule, so that R&D team can then trust in what their decision making are supported by. After creating knowledge network context from gathered information and knowledge, the network should be organized for routinizing network activities, in the third stage in knowledge network shell. In CKL model, establishing a "network heartbeat" [2] would be the most important part in this stage. Network heartbeat decides the frequency of R&D project activities routine. The routine activities of R&D project in CKL model are the reusing of knowledge toshorten the TTM and decrease development cost. In one hand, the frequency that the team recalls the knowledge should be dynamic change with the situation of the project going on. On the other hand, new available knowledge generated from each R&D team should be positively passed to each other via the concurrent knowledge engine. The fourth stage in this shell is leveraging network result. In this stage, the value of each R&D process are considered and ranked in order toperform the selecting stage in virtual value chain shell to extract the knowledge of identifying what are most important process and what might reduce the R&D TTM or so on.

The fifth stage of knowledge network shell, feeding knowledge back to next project or called post-project review, is added in order to utilize the knowledge that created through the network and to link all other stages into a spiral expending loop. The knowledge extracted from each R&D project must be fed back to organization through the post-project review process to synthesis its value [10]. While valuable knowledge rules diffuse to other ongoing R&D projects through CKE as soon as the knowledge is extracted, the organization is learning from previous R&D project and the R&D related knowledge expands. Therefore, the knowledge network shell becomes a spiral expending loop that the knowledge expends concurrently with each single R&D project and shared among every R&D projects.

3.4 R&D Collaboration Level

In this level, R&D activities are happening practically. Specifications are defined. evolution and experiments are performed. The most important part, knowledge from previous R&D projects is reused to help current project reducing TTM or avoiding similar mistakes.

In the initiation of a R&D project, the target and specification of the project is defined. The specification defining process could be referred to previous similar R&D project for the allocation of resource, the configuration of schedule and so on. After specification is defined, in the traditional way the project should be start. But in CKL model, the project must be start after the process of knowledge recalling. In this stage, knowledge rules are reused by their ranking of helping shorten TTM. With the help of these rules, the evaluating process would be shorten and optimized. This could lead to shorten TTM and decrease development cost.

After the evaluating process, each used knowledge rule is re-scored and re-ranking. A correct rule would be rewarded, but aninaccurate one would be punished. So the ranking of rules might be changed. Finally, a post-project review process reviews the project for the reason of failure and success. These experiences could be then shared as knowledge to other R&D teams via the CKE concurrently.

For example, knowledge about how to avoid failure or how to approach success is recalled. Or some knowledge rules might indicate the most important experiments among all while some others are not so important and might be skipped to reduce unnecessary cost. In the post-project review process, new knowledge rules would be found and synthesized concurrently with the old ones.

3.5 Summary of CKL Model

Table 1 summarizes the CKL model. With CKL model, the two major identified barriers faced by R&D collaboration – information sharing and organization learning – could be overcome by the employment of CE and knowledge management. CE plays a role of concurrent sharing of information and knowledge. Base on CE, the concept of VVC and knowledge network could provide a concurrent environment to extract, organize and refine experience and knowledge. The R&D collaboration could be then enhanced with the concurrent information sharing and organization learning. This could lead to shorten R&D TTM and further more, to increase competency of high-tech industries in the globalization.

4. Conclusion & Future Work

The CKL model integrates various artifacts and enhances the concurrent knowledge refining anddiffusing, so that the R&D project collaboration could be improved continuously with the concurrent knowledge learning environment. In other words, the CKL model is itself an experts system with dynamic and grow-able knowledge base. The knowledge of CKL model will expand with new artifacts generated from every R&D project, and are refined through knowledge selection during every R&D projects. This is the key to shorten TTM.

The future work of this research is to implement CKL model as a web-based environment and validate it in the industry. The CKL methodology and the implemented environment would be introduced to the world-class high-tech industries in Taiwan. The semiconductor or optoelectronics industries are the first priority. Through the cooperation of industry and academics, the expected benefits are as follows:

1) The TTM of R&D projects could be shortened by the capability of knowledge and experience recalling in CKL.
2) The quality of real time information / knowledge sharing could be improved through the employment of CKL.
3) The efficiency of R&D project collaboration could be continuously improved by CKL model for the improvement in concurrent knowledge reusing and information sharing.

In addition, CKL model delivers the reference model for the R&D projects and knowledge management to shorten the TTM. Besides, this research proposes a suggestion for the refinement of the virtual value chain [8] and the knowledge network [2] by integrating them with the concept of concurrent engineering [14]. These could contribute to the field of new technology innovation and knowledge management.

Table 1: Summary of the CKL model

Component		Description	Major Function
Kernel	Concurrent Knowledge Engine (CKE)	CKE is the kernel of the CKL model, served as a knowledge base which collects and diffuses knowledge concurrently.	● A centralized knowledge base ● Diffusing knowledge and information ● Enabling a real-time knowledge sharing environment
Infrastructure Level	Shell 1: Virtual Value Chain (VVC)	VVC is the basic concept of extracting value-adding knowledge from physical process.	● Defining the five value-adding stages ● Extracting "virtual value" from "physical process"
	Shell 2: Knowledge Network	Knowledge Network forms a method to extract, utilize, and refine knowledge which extracted from physical process.	● Linking the virtual value chain concept and physical R&D processes ● Defining the standards for knowledge formation, reusing, ranking, and refining.
Application Level	R&D Collaboration	This level defines a looping process for R&D collaboration, which is not as the traditional sequential way. Concurrent knowledge reusing and post-project review are the major method to enhance R&D collaboration.	● Collaborating different R&D projects by mutual knowledge reusing ● Recalling knowledge to shorten TTM and decrease cost ● Refining knowledge as an organizational learning process through the post-project review

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