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Knowledge kanban system for virtual research and development

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ABSTRACT

Virtual research and development (R&D) is inevitable to reduce the product life cycle. Enterprises tend to rely on their foreign partners for supporting technology and knowledge acquisition to conduct and improve firms' product development with low R&D risk. R&D is a highly creative and knowledge-intensive activity, Therefore, efficient knowledge flow, which transmits the right knowledge to the right people at the right time, is key to improving efficiency of the R&D process.

Kanban supports visual production control using the card of providing information to regulate the flow of inventory and materials. To enhance the knowledge flow efficiency in the virtual R&D process, this study proposes a knowledge *kanban* system utilizing the philosophy of *kanban* management and knowledge engineering techniques. Employees can quickly, easily, and exactly determine what knowledge they need to learn, create, share, and maintain by the knowledge *kanban* system. This system assists employees to do the right thing, to reduce the cycle time of R&D processes, and to enhance the reuse of knowledge, to create new knowledge.

To achieve this objective, this study first proposes a knowledge flow model in virtual R&D based on the analysis result of knowledge in virtual enterprises (VEs), and then designs the knowledge *kanban* model according to the knowledge flow model in virtual R&D and proposes the knowledge *kanban* functional framework based on the knowledge *kanban* model. Finally, this study develops the related technologies to implement the knowledge *kanban* system. The knowledge *kanban* system is an effective tool to facilitate knowledge creation, storage, transmission and sharing for R&D engineers to develop knowledge in problem solving and product development, to improve enterprise competitiveness.

1. Introduction

Virtual research and development (R&D) [1,2] is inevitable to reduce the product life cycle. Virtual R&D develops differentiated products and services to meet market needs by multi-functional virtual enterprises, and whose communication, coordination, and cooperation among employees is supported by the Internet and information technologies and the principles of rationalization and collaboration [3–5]. Virtual R&D team members who do not work at the same time or place [6] often face tight schedules and a need to start quickly and perform instantly [7]. Therefore, virtual R&D management is recognized as an important task.

Kanban implements a manufacturing philosophy of producing what is needed in the right quantity, in the right place, and at the right time [8].Various *kanban* systems have been designed to control and regulate the manufacture of goods to follow quantity and timing demands. Except for goods, knowledge has also been recognized as an important source of competitive advantage and value creation [9], particularly for the R&D process. R&D processes can transform information of technological advancements and market demands into the needed knowledge for new product concepts and process designs [10].

Knowledge, such as design experience, design knowledge, and an existing product model, has great effect on new product development. Knowledge can facilitate collaborative product development, which enable different enterprises to contribute to a common development project objective. People can make abstractions and analogies between problems and use past experience and skills to solve new problems [11,12]. Because R&D is a highly creative and knowledge-intensive activity, easier access to data and documents can help firms reduce the development cycles and lead times [13]. Unfortunately, it is impossible for users to iterate all knowledge to determine the needed knowledge in large-scale knowledge bases, which involves a large amount of knowledge [14], and it is difficult for users to decide what knowledge is needed before they know it. Therefore, efficient knowledge flow, which transmits the right knowledge for the right people at the right time, is the key point to improve efficiency of the R&D process.

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Searching and sharing knowledge are major parts of knowledge flow, which stimulates organizational learning, innovation, and competencies. Presently, with the rapid development of network communication technology and information technology, people can acquire considerable knowledge from various channels by network communication technologies. However, additional available information and knowledge can result in "information overload," which impairs the learning desires of knowledge requesters. Consequently, providing more knowledge than needed, often results in poor knowledge utilization. Knowledge sharing refers to the exchange and discussion of knowledge among members of an organization, between internal and external teams, or between organizations to improve organizational competiveness through effective knowledge exchange, integration, and synergy [15,16]. Knowledge sharing in distributed environments requires more a priori trust than face-to-face communication [17]. However, trust depends on an implicit set of beliefs, which are vague. Trust varies with time, environment, and other factors. Consequently, trust is fuzzy and dynamic [18], very complex, and cannot be easily evaluated because of its inter-organizational and distribution characteristics [19].

This research develops a knowledge *kanban* system to facilitate acquisition and utilization of knowledge distributed across allied enterprises, to improve enterprise competitiveness and to help virtual R&D engineers develop knowledge of problem solving and product development. The knowledge *kanban* system is a pull system that facilitates knowledge transmission, by providing only the right amount and type of knowledge that an employee requires at the right time, using the concept of *kanban* management and knowledge engineering technologies. The knowledge *kanban* system is an effective tool to facilitate knowledge creation, storage, transmission and sharing to reduce project lead time and shorter new product development cycles.

2. Literature review

This section surveys numerous studies related to the aims of this paper, including *kanban* management, and knowledge identification in virtual enterprises (VEs).

2.1. Kanban management

Kanban is the Japanese word for visual card of providing information to regulate the flow of inventory and materials. *Kanban* has three rules [20]: (1) visualize the workflow, (2) limit work in progress (WIP) at each workflow state, and (3) measure the lead time (i.e., average time to complete one item). *Kanban* fulfills the function of visibility, production control and inventory control [21], and a *kanban* system is meant to introduce stability and predictability into inventories held to be responsive to market changes [22,23]. Besides manufacturing, *kanban* has been applied to software production as a process model for project management [24].

The traditional *kanban* system uses primary kanbans, which are namely, withdrawal *kanban* and production *kanban*. The production card authorizes the manufacturing of parts in the quantities indicated and the withdrawal card allows the movement of parts between operations. Other types of *kanban*, such as the supplier *kanban*, signal *kanban*, express *kanban*, emergency *kanban*, through *kanban* and common *kanban* have existed within the Toyota production system [25]. Huang and Kusiak [21] have further grouped the different types of *kanban* together into primary *kanban*, supply *kanban*, procurement *kanban*, subcontract *kanban*, and auxiliary *kanban*. The major advantages of implementing the *kanban* system, including: (1) reduces inventory holding; (2) improves material flow; (3) eliminates overproduction; (4) ensures control at the material handling level; (5) develops visual scheduling and process management; (6) increases response to market; (7)minimizes obsolete inventory; and (8)improve management of the supply chain [26].

Unfortunately, the traditional *kanban* system is not adequate in situations of unstable demand, processing time instability, non-standardized operations, long setup time, a great variety of items, and raw material supply uncertainty [27]. To overcome such problems, various types of *kanban* systems and related techniques have been developed. Adaptive *kanban* is allowed to change the number of *kanban* cards with respect to unstable demand [28,29]. A flexible *kanban* system (FKS) adjusts the number of *kanbans* in response to variations in demand and lead-time. FKS considers the interruptions caused by preventive maintenance or breakdown of the material handling system [30,31]. Decentralized reactive *kanban* (DRK) is developed for unstable changes in product demand [32]. DRK controls the inventories of each workstation independently, and therefore keeps the average work in process at a low level and reduces the mean waiting time of product demand. A dynamic *kanban* system can dynamically change the number of *kanbans* with respect to system demand and capacity [33]. A multi-*kanban* system (MKS) routes *kanbans* in a dynamic way to consider system state [34,35].

The most common problem with the paper-based *kanban* system is lost cards, which leads to material outages, waiting, extra cost, and eventually, a lower service level [36,37]. Conventional *kanban* systems lack the ability to track and monitor physical cards [38]. Given the rapid advance of Internet and web-based technologies, web-based *kanban* have been developed to better manage manufacturing logistics and supply chains in JIT management. A web-based system delivers various advantages, including minimized human errors, real-time tracking, performance monitoring, greatly enhanced information contents of *kanbans*, and instant delivery of *kanbans* [38]. The major benefit of the web-based system is flexibility; therefore, the web-based *kanban* is more suitable for the presently competitive environment.

2.2. Knowledge in virtual enterprises (VEs)

Virtual enterprises (VEs), as a network of various administrative business domains, cooperates by sharing business processes and resources to provide value-added services to customers [39]. The goal of VEs is to swiftly respond to market changes and customer needs by integrating resources among enterprises through business alliances. VEs do not have a fixed pattern and their members are engaged in common activities based on mutual benefits [15,40]. Upon completion of its objectives, a VE organization is dissolved or a new VE is quickly formed for new objectives [40–42].

An analysis of VE activities is necessary to understand the knowledge required for particular activities. Knowledge can be structured experiences, values, text-based information, or unique expert insights. Knowledge not only resides in documents stored in a knowledge management system, but also in daily routine tasks, processes, executions, and norms [43,44]. Categories of knowledge vary with perspective; therefore, this study considers three dimensions in categorizing knowledge in a VE.

(1) Abstractness: This dimension can be divided into (a) Formal Knowledge: conceptual knowledge derived by generalization, analysis, and validation of data collected by scientifically objective means; and (b) Practical Knowledge: specific job skills, experience-based rules, causal relationships, or input/output of enterprise activities derived from practices and