ORGANIZATIONAL ADAPTATION AND IMPLEMENTATION OF PRODUCT LIFE MANAGEMENT SYSTEM

Completed Research Paper

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Abstract

The advent of the product lifecycle management (PLM) system provides a Web-based IT platform that streamlines new product development (NPD) related processes by closely integrating the project team and the broader organization. However, there is a lack of systematic research on the use of PLM for better NPD management. The adaptation process for new technology is not yet well understood. This study analyzes how an intra-organizational team successfully adapted a PLM system to meet organizational objectives, achieved through interactions between multilevel users and the modification of system. The theoretical contribution of this study is the combination of product strategy and PLM system implementation, leading to the conceptualization of system usage for the analysis of adaptive behavior. Great research opportunities exist in applying this system adaptation concept to other areas of product development, e.g., how supply chain partners can adapt the system and achieve better performance.

Keywords: Adaptive structuration theory, product lifecycle management, collaborative design
Introduction

The history of product development research can be traced back to a stream of innovation research, focusing at a micro level on how specific products are developed based on an organization-oriented approach (Brown and Eisenhardt, 1995), i.e., decisions on product development projects within a single firm. The existing literature on product development is vast, covering perspectives from different research communities including marketing, organizations, engineering design, and operations management (Krishnan and Ulrich, 2001). However, mainstream research still lies in the domain of structures and processes by which individuals create products, which emphasize the organizational structures, roles, and processes that are related to enhanced product development.

The management of a development project entails decisions about the relative priority of development objectives. These include process performance metrics like lead-time and productivity, and financial performance metrics like profit, revenue, and market share. Product development processes are often executed in the “black box” of a development team. The flow of information in research and development (R&D) groups is versatile, and can be changed subject to different organizational requirements in different product design and development stages. Communication complexity within the project team can result in unpredictable outcomes, requiring managerial intervention to ensure the realization of organizational objectives. The main task of product development is to collect creative ideas and knowledge contributions from team members. The project team is often kept autonomous from the organization to ensure optimal productivity.

The development of new IT appears to be revolutionizing the practices of product development to a considerable degree. The benefit of new IT tools like PLM systems to manage product knowledge and support development decision making within organizations has been explored in greater detail (Krishnan and Ulrich, 2001), but little has been done to investigate the impact of IT on product development (Nambisan, 2003; Pavlou and El Sawy, 2006; Boland et al., 2007).

The implementation of any new technology, including PLM, can cause unpredictable impacts within the organization. We draw on prior research on technology adaptation theory to help better understand the potential impact of PLM on product development. Different organizations adopt different approaches in adapting new technology. An emergent perspective argues that the use of new technology is not deterministic; technology has interpretative flexibility and users of the technology are engaged in its constitution as they develop or use it (Orlikowski, 1992). Users of a technology are a source of innovation (Von Hippel, 1998) and reinvention (e.g., Johnson and Rice, 1984). The technology is emergent, improvised, and appropriated in diverse ways by diverse users. Hence, the way the adaptation process unfolds depends on the nature of technology and its interaction with users.

The following quotation from Orlikowski and Iacono (2001) illustrates the role of contextual factors in the implementation of IT.

IT artifacts are always embedded in some time, place, discourse, and community. As such, their materiality is bound up with the historical and cultural aspects of their ongoing development and use, and these conditions, both material and cultural, cannot be ignored, abstracted, or assumed away (p. 131).

Hence, we conceptualize PLM systems as embedded in specific organization and group contexts and these contexts have fundamental influences on the way PLM systems are implemented and used. Due to the complexity and high cost in developing enterprise information systems (EIS), packaged software has become the prevailing approach for firms implementing EIS, and the PLM system is no exception.

Because the implemented PLM system is packaged software, the built-in system functionality needs to be adjusted according to each layer of organizational needs. During system implementation, a strengthened operational process model will be developed to match the system platform. Top-down administrative intervention is conducted for all team members to achieve the organization’s key performance indicators (KPI), while the individual user reacts and adapts to the system norms in a bottom-up pattern. Therefore the EIS system implementation entails a complicated interactive process between the organization and individual users. Yet, previous research does not deeply investigate adaptation problems among internal organizational processes, the usage model, and the development of KPIs. Hence this study addresses the following research question:
How could an organization approach technology adaptation based on usage behavior to best achieve organizational objectives for the implementation of a PLM system?

**Literature Review**

**NPD and PLM**

Successfully developing a new product is always a challenge for a firm. For successful NPD, a firm must be able to develop an innovative product that appeals to the customer and manufacture it in large quantity to reap profits from mass marketing (Verworn et al., 2008). One way to potentially improve new product development outcomes is to utilize IT tools (Nambisan, 2003) such as PLM. In fact, many senior executives believe that IT enables innovation (O’Mahony et al., 2003) and companies are increasingly using IT to support and enhance their NPD process (Cooper, 2007), even for their open innovation practices (Dodgson et al., 2006). Correspondingly, there is a growing stream of empirical research about the role and usage of IT in NPD (Barczak et al., 2007; Barczak et al., 2008).

As NPD covers a wide organizational area (Ulrich and Eppinger 2000), a collaborative working structure embedded in PLM system has the merits of virtual organization. The major challenge of NPD for a project team is how to integrate the technical knowledge required for the project to generate benefit to the organization. The use of PLM can have contribution from this perspective. Taken as a whole, little empirical research has been undertaken that explores the use of IT in the NPD process. Therefore, it is necessary to identify the extent to which a firm deploys PLM in the support of strategic and operational tasks such as NPD activities (Boynton et al., 1994).

**Technology Adaptation Theories**

Increases in organizational proficiency through IT normally come from how people use these technologies, rather than the technology’s specific characteristics. Yet, interestingly, people in organizations usually have their own fixed model of using IT and the implementation of new IT can create discontinuity within an organization. Adapting the same IT to different enterprises elicits different adaptation behaviors and results in different implementation outcomes. Thus, studying adaptation behaviors is a valuable line of inquiry.

Leonard-Barton (1988) proposed the mutual adaptation model for technology and organization to reduce misalignment between techniques, delivery systems, and performance criteria in the technology adoption process. As there are cycles of disruption in technology use, the performance impact is often the final target for the implementation of a given technology. Thus, Leonard-Barton (1988) believed that the misalignment among technology and organization can be attributed to different alignment statuses such that the degree of adaptation can be estimated. Adaptations occur continuously in response to misalignments, gradually leading to a successful alignment.

DeSantics and Poole (1994) proposed Adaptive Structuration Theory (AST) as a framework for studying variations in organization change that occur when advanced technologies are used. The focal point of this theory is emphasizing the impact of technology, work practice, and organizational environment on a user group's structural appropriation behavior. If appropriation accords with technology design concepts, decision making performance is improved. Tyre and Orlikowski (1994) characterize adaptation as a highly discontinuous process, where discontinuities occur during brief windows of opportunity which open the constraint set. This difference may reflect different conditions in the field rather than invariant theoretical conclusions.

Majchrzak et al. (2000) further combine the theories of Leonard–Barton (1988), Tyre and Orlikowski (1994) and Desantics and Poole (1994) which are adaptation models of technology and organization, discrepant events of technology adaptation, and adaptive structuration theory. Majchrzak et al. (2000) believes that the models differ in the continuity presumed to occur in the adaptation process, which can be continuous or discontinuous depending on different conditions in the field rather than invariant theoretical conclusions.
Change Management and BPR

Previous research in technology adaptation mainly addresses the pattern of adaptation process when new technology is introduced. However, introducing new technology to organizations often accompanies organizational change issues such as process redesign and cultural adjustment. Change management addresses a structured approach to transitioning organizations from a current state to a desired future state. It is an organizational process aimed at empowering employees to accept and embrace changes in their current business environment (Paton and McCalman, 2008). The management of change can be deemed as a process. A generic model of the change process consists of three stages: diagnosis, strategies and plans, and implementation (Hayes, 2007). Diagnosis is about reviewing the present state and identifying the preferred future state. The stage of strategies and plans is about to prepare and plan for implementation. The last stage is to implement change, and the focus shifts from planning to action. Efforts must be given to monitoring and control to ensure that things happen as intended.

BPR is often presented as a “top-down”, organization-wide approach to transforming organizations. It is particularly important in firms that have a strong corporate culture or rely heavily on legacy systems (Grover et al., 1995). BPR should provide dramatic results. The BPR methodology includes the five activities: prepare for reengineering, map and analyze As-Is process, design To-Be process, implement reengineered process and improve continuously (Muthu et al., 1999). The main objective of As-Is analysis is to identify disconnects that prevent the process from achieving the desired results. Having identified the potential improvements to the existing processes, the To-Be models are developed using the benchmarking technique, which involves comparing both the performance of the organization’s processes and the way those processes are conducted with those of relevant peer organizations to obtain ideas for improvement. After the To-Be model is set, discrepancy events occur frequently in the organization which entail turning away from the planned scenario as set in the To-Be model, requiring adjustments to achieve the organizational objectives. The literature on technology adaptation presents different approaches to dealing with this problem. One group believes that the organization will make adjustments automatically (Leonard-Barton, 1988), and some believe a solution plan will emerge through the user’s interaction with the technology (Majchrzak et al., 2000). However, a clear adjustment process is missing in both explanations.

Research Methodology

Due to the long project duration, technological complexity, and the lack of a successful PLM implementation, we present a single case study. Case studies are a universally accepted method for discussing and analyzing complex phenomena involved in the implementation of advanced and complex technology into an organization (Alavi and Carlson, 1992; Orlikowski and Baroudi, 1991; Yin, 1994). Additionally, the implementation period for PLM technology is relatively long (frequently exceeding 1 year), and AST can assist with interpreting results based on long-term processes (Markus and Robey, 1988).

Research Framework

Successful product development involves relatively autonomous problem solving by cross-functional teams bringing high communication and organizational abilities according to the demands of the development task. This perspective also highlights the roles played by project leaders and senior management in providing problem solving discipline through a product vision. There is an emphasis on both project and senior management to, on one hand, provide a vision for the development effort and yet, on the other hand, to provide the team with autonomy. Thus, we can portray product development as a balancing act between product vision developed at the executive level and problem solving at the project level. The balance of these actions must be achieved through adjusting the PLM usage behavior.

In BPR, the packaged software implementation usually applies the As-Is and To-Be models. The AST theories then study the impact made by contextual factors on system usage behavior. In light of institutional and cultural challenges of organizational change, we combine the two models described above, and consider document access, knowledge capture, knowledge sharing, and decision making as usage behavior (Majchrzak et al., 2000). Thus, we propose a technology adaptation model based on formal
interventions exercised by management, as shown in Fig. 1. This model is used to discuss how enterprises achieve R&D goals through adjusting usage behavior on the PLM system.

**Research Design**

**Case Description**

The case used in this research is representative and has been explored deeply in terms of its context. To improve understanding of how the adaptation process leads to the required organizational benefits through system implementation, enterprise implementation of PLM systems was examined through a goal-driven technology adaptation model.

Company E produces small and medium-sized LCD panels. In 2003, the company had annual revenues of USD$111.3 million and an annual growth rate of 110%. The company’s revenue comes from LCDs used in cell phone related products, consumer electronics, industrial equipment and medical applications.

The company adopted a Build To Order (BTO) business model, and is one of the best-performing LCD makers in Taiwan. Customers from a variety of industries are drawn by the company’s highly-customized products. Company E uses PLM to control NPD project time scheduling and built a platform for project technical knowledge sharing to satisfy customer needs, achieve operational objectives and establish technical support.
Implementation Objectives

NPD implementation was expected to bring the power of collaborative product design to integrate scattered information and resources in one platform for the whole supply chain. It was also hoped that new product specifications from upstream suppliers could be merged earlier into product design activities to reduce time to market.

Integration increased operational flexibility and competitiveness. Through collaboration design, technical resource integration and collaborative IP management, project documents were integrated to form the company's largest knowledge database, which can be used to provide solutions for product design issues, reveal the current status of project operations and provide answers to product enquiries. The purpose of the overall structure is to build a model based on the spirit of knowledge creation and value collaboration to realize the strategy of supply chain technical integration. Thus, Company E’s goals in implementing PLM are to reduce product and project management costs, and to increase customer satisfaction.

Data Collection

In this context, project development in Company E predominately consists of the main designers in various departments, and the PMs who are more experienced engineers. All project teams are monitored by the R&D Manager. Coordination of project operations takes place through face-to-face communication and meetings. Analysis of the case study project is based on a semi-structured questionnaire and in-depth interviews with the project decision maker (CEO), PLM system administrator (CIO), and ten project-related organizational personnel, from MIS, R&D, sales, product technology and procurement. In total, this study collected 70 questionnaires, interview data, and company documents relating to NPD. All sources of evidence were reviewed and analyzed together to insure the triangulation of data.

Case Analysis Procedure

As-is and To-Be Analysis

The term of enterprise information systems (EIS) originally implied systems designed for planning the use of enterprise-wide resources. Although the enterprise information systems originated in the manufacturing environment, today's use of the enterprise information systems involves much broader scope. Enterprise information systems typically attempt to cover all basic functions of an organization, regardless the organization's business types (Jacobs and Bendoly, 2003).

The As-Is phase in the system implementation is typically a review of extant processes. The To-Be phase tends to be the plans of process improvement and desired technological features of the system according to organization needs. Normally, the system implementation is project based. After completing the As-Is phase, the process improvement is then carried out. A customized system is developed after the operation of processes has reached preset objectives. The weakness of such approach is that the customization system has not been tested in the actual environment in the organization.

Since systems become huge and complicated nowadays, current EIS implementation is package based. After completing the review of extant processes, the organization builds desired functions into the system. The actual IS implementation process is shown as Figure 2. Users examine the current operation processes and induce the best model of system structure. Based on users’ needs, the optimized process model is constructed, which is typified by the Initial Implemented To-Be stage in Figure 2. Yet, as the operation processes are performed between the organization and users, the complexity of interests from different parties and operation processes become increased. Occasionally, unforeseen and unexpected conflicts emerge, which is termed discrepancy events, and Appropriated To-Be stage is reached under such circumstance. At this point, the ultimate goals of system implementation are not reached yet, and the structure in the Final To-Be stage still needs to be constructed through the Process Redesign. The Final To-Be structure emerges when the emergent structures appear after the PLM is implemented and preset goals are reached.
According to Figure 2, this study analyzed three phases in PLM implementation: Initial Implemented To-
Be, Appropriated To-Be, and Final To-Be. We investigated the impact of contextual factors such as PLM 
technology, organizational environment, and group structure on the decision processes on collaborative 
product design through four aspects: document access, knowledge capture, knowledge sharing, and 
decision making.

Customized products are slight variations of standardized configurations and are typically developed in 
response to a specific order by a customer (Suomala et al., 2002). Company E's production model are 
customized products, which means new products have various configurations, and profit depends on 
product cost, R&D, and production efficiency. To maximize total benefit through increased 
competitiveness, Company E chose the Windchill PLM system as its primary platform.

Operational processes prior to the implementation project are referred to as the As-Is model. At this stage, 
new product design is performed through email and project meetings across R&D and supporting 
departments inside the company. To communicate with suppliers, the transmission of technical 
information is performed through FAX or email.

Due to certain uncontrollable factors in NPD projects, businesses in this industry have long had trouble 
ensuring that upstream suppliers access to technical information on raw materials and downstream 
customers access to timely information related to product tests and specification confirmation. Under 
strong competitive pressure, Company E implemented the PLM platform to improve the NPD design 
environment and integrate up and downstream resources to achieve knowledge sharing and accelerated 
product delivery. Analysis of the As-Is model led to a solution based on PLM functionality, referred to as 
the To-Be model.

Table 1 presents the As-Is and To-Be models for Company E in light of its NPD usage behavior along the 
organizational hierarchy.

**Discrepant Event Analysis and Business Process Redesign**

Company E uses the PLM system as the foundation for process optimization. An initial To-Be model is 
developed based on PLM’s technological features to deal with the drawbacks in the As-Is model. Yet, 
implementing the model leads to discrepant events among the organization, group, and technology; that is 
a gap occurs between the planned and actual actions of the To-Be model. The gap can result from lack of 
access to needed technical information, discomfort with the interface, or disintegration of system 
resources, resulting in poor performance results for the initial To-Be model.

The gap between the planned and realized To-Be model can be explained on the basis of organization, 
group, and technology. Below, we discuss these various aspects and propose possible strategies to 
minimize the gap. Rectification with BPR results in a refined structure which can be used to reduce the 
incompatibility between the initial To-Be model and actual system usage. The emergent structure will be 
the one that satisfies the organizational goal. Based on the implementation of the initial To-Be model, 
Table 2 provides contributing factors for discrepant events as well as emergent structures after re-
designing the implementation processes.

<p>| Table 1. Review of As-Is and To-Be Models Based on Desired Features of PLM System |
|---------------------------------|------------------------------------------|------------------------------------------|
| Stage                          | Structure                      | As-Is Model                                      |
| Document Access                | Organization Environment        | In the project process, engineers call a weekly meeting. Meeting minutes are compiled by project engineers and audited by the CEO in hard copy or email format. |
|                                |                              | In the project integration meeting, the project manager makes a detailed record of meeting content and project status. During the project audit process, the CEO controls |</p>
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<th>Group Structure</th>
<th>Knowledge Capture</th>
<th>Decision Making</th>
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<td><strong>At the end of the project stage, a full copy of all documentation is passed to the engineer responsible for the next stage. This process repeats until the project is complete. The data in the supplier material design diagram is exchanged by FTP, and the detailed specifications are confirmed by email or telephone.</strong></td>
<td><strong>The project status at any time through the system’s notification function.</strong></td>
<td><strong>Microsoft Office is used during the project process to collect technical information to be shared on hard copy.</strong></td>
<td><strong>Design activities are performed through AutoCAD software. Audits are conducted through paper documentation and email.</strong></td>
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<td><strong>The project engineer uses the Pro/E system as a design visualization interface. The project manager communicates with the project engineer through the Pro/E system to review progress, modify designs, and revise documents.</strong></td>
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<td><strong>The project manager and project engineer use the Pro/E system to discuss project blueprints and manage product versions.</strong></td>
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<td><strong>After project completion, the project engineer provides a hard copy of the design diagram data to the lead engineer for reference. Project minutes describe problem resolutions.</strong></td>
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<td><strong>PM provides online project status and cost configuration updates through the Pro/E function. CEO immediately clarifies project concerns in the meeting, and updates product strategy.</strong></td>
<td><strong>The Web platform immediately updates the project document database; the Product View function is used for collaborative discussions on project documentation.</strong></td>
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<td><strong>Product design drawings and project document are offered in hard copy or electronic file formats. Customers and suppliers exchange data via FTP.</strong></td>
<td><strong>Project engineer develops a specialized control process to manage project progress, and the CEO can use the system’s subscription functions to track project progress.</strong></td>
<td><strong>System provides database search and backup access based on access privilege.</strong></td>
<td><strong>The project engineer collects product design drawings, cost analyses, and test results on returned products, and forwards this information to the R&amp;D manager and the CEO in paper reports. The CEO provides direct comments on the reports.</strong></td>
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<td><strong>Project engineer provides other team members with a search function to access the database with preset roles and authorities, and also to share latest product version information.</strong></td>
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<td><strong>In the project closure meeting, the project manager uses the Pro/E system’s web tools to link to technical reports and explain product technical specifications and cost structures. After the meeting, all meeting minutes are audited by the CEO to complete the project work.</strong></td>
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<td><strong>Lead engineer tracks the CEO’s key requirements in the meeting, and explains project progress to the CEO using weekly and monthly reports.</strong></td>
<td><strong>Project engineer provides a hard copy of the design diagram data to the lead engineer for reference. Project minutes describe problem resolutions.</strong></td>
<td><strong>From time to time, the lead engineer discusses issues raised by the CEO with engineering team. Weekly and monthly summarized project progress reports are presented orally to the CEO orally with the CEO offering direct feedback.</strong></td>
<td><strong>PM provides online project status and cost configuration updates through the Pro/E function. CEO immediately clarifies project concerns in the meeting, and updates product strategy.</strong></td>
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<td><strong>Project engineer and the lead engineer design the diagram data on paper through face-to-face discussion, resulting in a hard copy design.</strong></td>
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<td><strong>Project document is supplied in hard copy, and the project engineer summarizes project problems given by the CEO. In the weekly meeting, project engineer discusses technique specifications and solutions to project problems with the lead engineer.</strong></td>
<td><strong>Online Product View function is used by the team to integrate ideas, solve communication problems, assist decision making, and manage documentation versions.</strong></td>
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<td><strong>Project document data is shared with team members in hard copy or electronic file formats. Project engineer provides project related data, and the accuracy of the data version is confirmed by the project engineer.</strong></td>
<td><strong>Project engineer uses the PLM Product View function to discuss collaborative design documents with customers and suppliers, and to discuss product design specifications during the meeting.</strong></td>
<td><strong>Weekly and monthly summarized project progress reports are presented orally to the CEO with the CEO offering direct feedback.</strong></td>
<td><strong>Microsoft Office is used during the project process to collect technical information to be shared on hard copy.</strong></td>
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<td>Stage</td>
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<td>Discrepant Events</td>
<td>Causes for Process Redesign</td>
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<td>Document Access</td>
<td>Organization Environment</td>
<td>Engineer avoids formal responsibility resulting in incomplete project document management. The overburdened R&amp;D manager entrusts the engineer to self-audit the project documents, with the result that the CEO cannot completely control the project status.</td>
<td>Engineer simply describes the content of project technical reports, and the PM does not request complete details. The CEO cannot fully understand the project status.</td>
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<td>Group Structure</td>
<td>Project engineer does not update the version after the project meeting, causing confusion regarding the document’s current version and incorrect system records.</td>
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<td>Employees believe their development and capabilities are important, and spend more attention on personal promotion and competition than on project tasks and documentation.</td>
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<td>Technology</td>
<td>PLM project system cannot audit the relationship between the data and project. Project records are fragmented, rendering internal project data useless.</td>
<td>Project engineers consider project solution processes as personal assets, and fail to store complete technical documentation on the platform. The project file only stores basic diagram data.</td>
<td>Documentation auditing process is based on ISO standard formats. Project manager audits the document content and ensures knowledge integrity.</td>
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<td>Knowledge Capture</td>
<td>CEO provides oral project feedback face-to-face or by telephone, making it difficult for the CEO to follow up on how feedback is implemented.</td>
<td>When auditing documents, the CEO relies on explanations from the PM to understand project progress.</td>
<td>During the audit process, recording project solutions is an important annual assessment item for the CEO, ensuring that the CEO can make prompt decisions.</td>
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<td>Group Structure</td>
<td>In the project process, the Project engineer develops reports and records without adequate sophistication. Also, the PM lacks a management mindset, and project documentation is incomplete, reducing the overall effectiveness of the project.</td>
<td>The project engineers consider techniques used as their personal assets, and tend not to document solutions of critical problems. They also backup important documents in their personal computers.</td>
<td>Company rewards engineers based on their patent counts, and provides cash awards based on the degree of contribution to those patents.</td>
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<td>Technology</td>
<td>Large design drawing file sizes cause problems for file sharing and searching.</td>
<td>Project engineer frequently needs to download project documentation from the database, reducing the network quality.</td>
<td>System provides a security mechanism for controlling document safety. The data in the knowledge database can only be read online, and cannot be accessed outside the internal network.</td>
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<td>Knowledge Sharing</td>
<td>Given typically long project durations, the CEO is unable to offer comprehensive project review comments just from reading fragmented data, and frequently relies on the PM for time-consuming oral explanations, delaying the project schedule.</td>
<td>Document content described too simplistically, and the content knowledge quality is substandard. Limited project time pushes the PM report to the CEO orally, making it difficult to record solutions.</td>
<td>CEO audit process examines the integrity of project opinions, and develops the KPIs for the project team based on summarized project reports.</td>
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<td>Group Structure</td>
<td>Project engineer sometimes does not store the latest version of project system design documentation, and version synchronization is unreliable</td>
<td>Engineer backs up all important project documents to his or her own computer, and holds the project documentation hard copy for PM requires users to note the date and reasons for change when updating the document version. The PM approves the accuracy of the project documentation based</td>
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4.3 Emergent Collaborative Processes in Product Development

During the initial implemented To-Be phase, discrepant events are identified from the interactions between users and the system. When solving the discrepant events through BPR, emergent structures are revealed in the implementation process. These emergent structures have different processes from those structures set in the initial implemented To-Be phase. The differences in the implementation process stem from the interaction between usage behavior and the system. To reduce product cost and increase customer satisfaction through system implementation requires inter-organizational BPR along with change in the way the organization interacts with suppliers and customers. Table 3 summarizes BPR activities and describes solutions for problems derived from discrepant events through the monitoring of management levels and response to individual user opinions.

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<th>Gap Adjustment</th>
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<tr>
<td>Document Access</td>
<td>Project manager summarizes important items from engineers in a report. The CEO sets annual evaluation criteria for the project based on the integrity and contribution of the report. The organization establishes ISO standard compliant system control documentation for PLM. The system includes a function to check project documentation.</td>
</tr>
<tr>
<td>Knowledge Capture</td>
<td>During the annual evaluation of engineer project contributions, awards are given based on the number of patents received. The system provides a security mechanism to protect documentation and ensure the database cannot be accessed outside the business network.</td>
</tr>
<tr>
<td>Knowledge Sharing</td>
<td>Project manager audits the dates to manage documentation versions, using an encoding system (DRM) to protect project information.</td>
</tr>
<tr>
<td>Decision Making</td>
<td>Product View function is used to solve technical problems between suppliers, buyers, and the organization. The online auditing function records the process of finding solutions, managing document versions, and protecting the organization’s intellectual property.</td>
</tr>
</tbody>
</table>

Decision making is critical to achieving organizational goals. To integrate the opinions of all stakeholders, Company E developed a collaboration product design process in the BPR process. Figures 3 and 4 show the critical decision making steps to achieve organizational objectives through the PLM system’s online functions to deal with customers and suppliers, and to solve problems in real time.
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Customers report product defects. Project engineer searches the project database to find the relevant product solution process.</td>
</tr>
<tr>
<td>2</td>
<td>Project manager calls a meeting of engineers and customers using the online function of Product View and Pro/E to discuss the product defects.</td>
</tr>
<tr>
<td>3</td>
<td>If the defect is related to product materials, the project manager calls the engineer, customers, and suppliers for a meeting using the online function of Product View and the simulation function of Pro/E 3D to discover the relationship between suppliers and materials.</td>
</tr>
</tbody>
</table>

**Figure 3. Customer Investigation Process**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>After the meeting, the project engineer supplies required standard report, at which point customers can review the report online.</td>
</tr>
<tr>
<td>5</td>
<td>After customers review the report, the project manager uses the online function of Product View to examine detailed design specifications of products and re-check the specifications with customers.</td>
</tr>
<tr>
<td>6</td>
<td>Project manager uses the internet function of Product View to provide solutions based on the results of an examination of the material specification.</td>
</tr>
</tbody>
</table>

**Figure 4. Customer Product Problem Resolution Process**
As shown in Figures 3 and 4, Company E uses the online function of the PLM system to call collaborative meetings with customers and suppliers over the Internet. The system provides 3D pictures, diagrams, and simulations to help locate problems and find solutions. In the As-Is phase, problems were discussed using hard copy documents and the telephone, leading to frequent misunderstandings and misjudgments which can be avoided through the use of web meetings, product simulations, and document presentation functions, thus avoiding delayed product launches.

There are interactions between performance metrics in supporting product development decisions (Krishnan and Ulrich, 2004). We employed potential interactions like development time, development cost, product performance, and product cost for evaluating the performance impacts resulted from BPR implementation (Table 4).

![Table 4. Project Outcomes in Terms of Organizational KPI](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>KPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development Time</td>
<td>Product Planning, Design and</td>
<td>Shorten 23 days (eliminate 22.3%)</td>
</tr>
<tr>
<td></td>
<td>Development</td>
<td></td>
</tr>
<tr>
<td>Product Development Cost (*a)</td>
<td>Intellectual Property (IP)</td>
<td>IP Manage benefit: 0.06 million/year</td>
</tr>
<tr>
<td></td>
<td>Management Cost</td>
<td>(1,118 days x 53.7/day = 0.06 million)</td>
</tr>
<tr>
<td>Collaborative Product Design</td>
<td>Minimization of design changes</td>
<td>Product benefit: 0.32 million/year</td>
</tr>
<tr>
<td></td>
<td>due to supply chain synchronization</td>
<td>(Contain: Custom error cost, Supply error cost, etc.)</td>
</tr>
<tr>
<td></td>
<td>Minimization of engineering</td>
<td>Process benefit: 0.08 million/year</td>
</tr>
<tr>
<td></td>
<td>change costs due to collaborative</td>
<td>(Contain: WIP cost, Stagnant material, etc.)</td>
</tr>
<tr>
<td></td>
<td>team work</td>
<td></td>
</tr>
</tbody>
</table>

(*a: Normally Company E engages in five projects per year, with each project expected to yield seven material Intellectual Property analyses, totaling thirty-five required annual IP analyses.)

**Performance Impacts of the Implemented PLM System**

The ability to successfully develop new products is a key competitive advantage. Successful NPD requires a firm to be able to develop an innovative product that appeals to the customer, and be able to manufacture it in large quantity to reap profit from the mass market (Verworn et al., 2008).

Figures 3 and 4 show that, when faced with competition pressure in the market, Company E was able to use the collaboration techniques in the PLM system in the NPD stage to accelerate interacting with upstream suppliers and downstream customers to integrate project techniques and improve NPD management.

The use of BPR and the PLM system influences decision making at each level in the organization. In the As-Is phase, Company E established organizational objectives which were achieved through the BPR process and the implementation of the PLM system. In the final To-Be phase, the standardized user operation processes were established. In the implementation process, the CEO checked organizational performance through a top-down approach, and the project team requested the establishment of new managerial rules to increase organizational performance through a bottom-up approach. Therefore, given the predefined performance goals, an emergent structure was formed in the adaptation process involving both top-down and bottom-up approaches. Such an emergent structure is the result of the inter-organizational BPR process. Through the new organizational operation process, Company E was able to reduce product development costs and achieve its preset implementation goals.

**Case Study Analysis**

The implementation of the PLM system not only helped process adjustment, but also played an important role in knowledge creation and sharing throughout the enterprise. A pragmatic view of "knowledge in practice" was developed, describing knowledge as localized, embedded, and invested within a function and how, when working across functions, consequences often arise that generate problematic knowledge
boundaries. Therefore, developing boundary knowledge to combine different perspectives to reach consensus is important (Carlile, 2000).

As shown in Figures 3 and 4, Company E uses the PLM system’s Internet meeting and 3D simulation functions to integrate and simultaneously analyze product problems and customer feedback, and then to propose solutions. In the process of upstream and downstream product analysis, localized knowledge was shared and knowledge was embedded in the development of the products. Through the Internet meeting and 3D simulation functions, the company was able to efficiently manage new product structures, reducing the product development cycle, enhancing product reliability, and accelerating early phase R&D. Prior research indicates that knowledge sharing improves product development (Brown and Eisenhardt 1995; Dougherty, 1992; Ozer, 2004, 2005; Sheremata, 2000). Our research shows that, given organization and group adaptability and an appropriate technology structure, project members will share appropriate knowledge created in the project process. Given the integration of project technologies, the organization can be more tightly integrated with its customers and suppliers in a partnership. Project team R&D capabilities are also enhanced through the use of the project knowledge database, and the enterprise is able to improve organizational product development behavior, thus increasing profitability.

**Discussion**

**Institutional and Cultural Perspectives on Organizational Change**

Company E used the PLM system to build up the enterprise project management system platform that integrates all project documents, meeting minutes and design pictures. Company E can also use this platform to perform projects auditing, information sharing, and technical solution functions with the suppliers synchronously. As the Vice-President of R&D pointed out, "The suppliers and we can collaborate with product patent analyses for collaborative product designs in the future by using the project management platform. Thus, our company can avoid confrontation with the IP infringement design in advance, and build up the strategic plan for IP, and establish the correlation relationship for customer and technique demand". Although the ultimate purpose of the PLM platform is to integrate the technical knowledge of products, but the real world operations must face institutional and cultural challenges.

The challenge that the system faces is a Patent Infringement and the norm for the standard document. The supplier keeps the self-owned techniques as the company secret and reluctant to disclosure the particular techniques in the collaboration process. Only the solutions for some parts of the problem are proposed. Thus, only certain parts relating to technical integration are resolved, and it is hard to go deep into the heart of to improve the product weakness. Although the data and document of project management system are kept in the format required by ISO for recording the solutions for technical problems, the engineers only record generic and oversimplified content of the document, and no formal requirement is found to standardize the detailed record format.

The challenge from the culture aspect is about the attitude towards dealing with the technique knowledge. The information uploaded onto the platform by the engineer is only limited to the partial solutions to the product improvement, and he or she would obtain more valuable information and references from the knowledge and patient database.

The main reason is that the engineer treats the problems solving knowledge as his or her own property and tends not to share it. The knowledge becomes the engineer’s key to survive in the company and the stepping stone for a better job change in the future. Thus, the engineers tend to record the meeting minutes in their own computers and upload them onto the system rather than manage them directly over the online database.

**Promotion of Collaborative Process**

When Company E initiated its NPD project, organization mode employed was lightweight project organization (Hayes et al., 1988), which means that the members of the project came from various departments and the PM had no real powers of decision making and control. The PM therefore had to play the role of being the communication channels between departments in the project. The PM used the
platform to hold interdepartmental meetings, integrate the data for discussion across different departments, and request the engineers to modify specification plans. When the material suppliers were concerned in the technical level discussion, the PM called relevant departments to check product specifications and perform product simulation with suppliers directly based on the design blueprints through the use of 3D function in the online meeting as well as to find causes of problems. As the Field Application Engineer (FAE) in the case company revealed: the collaborative platform for project management is useful. When customers encounter the product related problems, the company and the upstream and downstream partners in the supply chain would discuss technical and integration issues based on the 3D function in the online meetings. We can use the 3D function to perform technical simulation, and the results would be recorded as meeting minutes, and simultaneously revise the design diagrams in order to unify the understandings of the problem.

Leadership and Intervention

Prior to the system installation, the CEO was involved in the project decisions frequently, audited projects, and provided rewards to the outstanding projects. Since the PLM system can display project results and their progresses, it is much easier for the CEO to carry out the reward system. After the system installation, the manager and engineers had to manage the operation process of the system and make the adaptation. While the project was ongoing, the engineers usually complained about the unfairness of the reward system from their project manager. It was frequently seen that the manager delayed audit schedule and missing checks on final document. Yet, the responsibilities on project delays and data errors were the engineers’. The major reason was that the manager was not familiar with the system interface, and cannot make quick and real time responses to online data. Thus, in addition to give pressure to the operational aspect of the engineers, the CEO also required the managers related to the project to provide rewarding rules based on the audit records in the system. It was hoped to increase the positive interactions between the manager and engineers.

Conclusions

Prior research in product development decisions has suffered from various complicated organizational flows. Only multilevel studies can resolve the conflicting results produced at different levels in that they examine the linkages between levels, such as discovering how individual contributions generate and sustain communities (Burton-Jones and Gallivan, 2007). Researchers have long suggested that a CEO’s product vision (e.g., ranking project priorities) influences product development performance (Brown and Eisenhardt, 1995). Yet, how the beliefs of top management affect the ability of individual team members to achieve organizational goals remains unaddressed. The multilevel research concept and supporting IT infrastructure needed to conduct multilevel PLM system use research has only recently matured to the point that would allow an in-depth case study.

This study employed AST to investigate the impact of organizational hierarchy on the user adaptation behavior towards the PLM system. As seen in Figure 5, our research results indicate that there are three contextual factors (technology, group structure, and organizational environment) affecting the use of PLM. Through interactions between multilevel users, modification of system features and process flows leads to the achievement of organizational objectives.
There are different functional perspectives of product development, including concept development, supply chain design, product design, and product strategy and planning (Krishnan and Ulrich 2001). The focus of this study is essentially a combination of product strategy and PLM system implementation, investigating how strategic goals can be realized through system use behavior. As PLM is used in nearly every aspect of product development, significant research opportunities can be found in applying this system use concept to other areas of product development. For example, a firm may intensively collaborate with its supply chain partners (e.g., customers or suppliers) in product development. How would the use of the PLM system affect the firm’s ability to manage its relationships with its partners? Addressing this issue will require theoretical support from supply chain management, IS implementation, and system use that should be considered in the future research.

Acknowledgements

This paper is partially supported by "Aim for the Top University Plan" of the National Sun Yat-sen University, Taiwan.

References


