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Informatization and Process Innovation: A China Case Study

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Abstract: A synergetic development between the informatization and the process innovation could enhance the competence of manufacturing enterprises and innovation capability effectively in the information era. A two-way relationship between the informatization and process innovation in manufacturing enterprises was studied in this research. In this study, the exploratory case study methodology was utilized and data was collected from four manufacturing enterprises in China. The analysis explored how informatization influence the process innovation from four aspects including R and D informatization, production informatization, management informatization and business informatization; the impacts of process innovation on informatization were also analyzed from three aspects including process technology innovation, process equipment innovation and process management innovation. The discussion thus indicates a two-way interaction between the informatization and process innovation. The case study demonstrates that the informatization could influence the process innovation through different aspects. On the other hand, the influential effect of process innovation on the four aspects of informatization was partially proven as well. A two-way relationship model was also constructed based on the case analysis.

Key words: Manufacturing enterprise, informatization, process innovation, interaction, case study

INTRODUCTION

Manufacturing enterprises are in an unprecedented information era now. The explosion of the information data and the dynamic change of the market demand force manufacturing enterprises to bring in advanced Information Technologies (IT) and Information Systems (IS) to improve their product and service. Meanwhile, traditional process innovation in manufacturing is facing a revolution in the circumstances of informatization. The informatization in manufacturing enterprises means the enterprising use of advanced computer technology, communication technology, automation technology and modern management methods to enhance and optimize the whole operation process including R and D, production, management, business, etc., (Huai-Li *et al.*, 2004; Fu and Bi, 2009; Zhang *et al.*, 2011). According to other references, the process innovation includes changes or improvements in process techniques, equipment or process management (OECD, 2005; Utterback and Abernathy, 1975).

The informatization and the process innovation are closely related. From one hand, informatization applications such as IT and IS could provide a favorable

environment and operation platform for the process innovation in manufacturing enterprises. The introduction of advanced information technologies could trigger the formation of new process technologies and modern process management modes. On the other hand, process innovation cannot be separated from informatization. The digitization and intellectualization need for realizing the novel process innovation has impacts on the informatization's development and application as well. A positive interaction between informatization and process innovation contributes to the overall performance of manufacturing enterprises and the mismatch between the two will lead to the productivity paradox. In this research, the manufacturing enterprise informatization was divided into R and D Informatization (RI), Production Informatization (PI), Management Informatization (MI) and Business Informatization (BI). And the process innovation is divided into Process Technology Innovation (PTI), Process Equipment Innovation (PEI) and Process Management Innovation (PMI).

The impacts of information technology or information systems on innovation have been studied by researchers. However, few studies has pay attention on the two-way interaction between the informatization and process

Table 1: Basic information of the 4 selected companies including their history, location, product and other information

Company	Telecom A	Appliances B	General equipment C	Equipment D
History	1987	1984	1989	1951
Locations	Shenzhen	Qingdao	Xuzhou	Harbin
Product	Telecom equipment	Electrical appliances	General equipment	Equipment
Revenue (2012)	¥203.9 billion	¥150.9 billion	¥87.1 billion	¥32.18 billion

Considering that the four companies in this research do not want to reveal their name, the four selected companies in this research are labeled as Telecom A, Appliances B, General equipment C, Equipment D

innovation from a systematic perspective. Therefore, this study explores the two-way relationship between the informatization and process innovation based on the data from six manufacturing enterprises in China and seeks to open the black box of the relation through cross-case comparison.

MATERIALS AND METHODS

The case study research is selected for this study to assess the real-life phenomena. As multi-case design allows for cross-case comparison (Eisenhardt, 1989), 4 manufacturing enterprises were selected in this research. Qualitative data which were gathered primarily through face-to-face interviews, was mainly used. The contact people include production managers, R and D personnel and top management team member, so, that data could be obtained from different perspectives. Before face-to-face interview, websites, annual reports, patents and other available resources of each case were carefully collected and analyzed. Telephone conversations and emails were also conducted to replenish the interview contents after the interviews.

Basic enterprise information of the 4 cases including the companies' name, history, location, product and other information are highlighted in Table 1. According to Table 1. all the four cases in this study have been set up for a long period and have good revenue with their products.

HOW INFORMATIZATION AFFECT PROCESS INNOVATION IN THE MANUFACTURING ENTERPRISES

R and D informatizations effect on the process innovation: R and D informatization contains the use of cloud computing, Computer Aided Design (CAD), Computer Aided Process Planning (CAPP), Product Data Management (PDM), Virtual Reality Technique (VRT), etc., in the R and D department or design department.

RI's effect on PTI: The cloud computing which changes the way industries and enterprises do their businesses in that dynamically scalable and virtualized resources are provided as a service over the Internet, serves better

when exploring innovation knowledge (Xu, 2012). The Telecom A has already applied cloud computing in its R and D activities. In order to be competitive, enterprises in manufacturing industries have to respond rapidly to dynamically changing market demands as well as unforeseen events (Wang *et al.*, 2012). In order to adapt to the market change and improve design accuracy, both Appliances B and General equipment C adopted digital design software and systems such as C-Mold, PRO/E, etc.

RI's effect on PEI: According to the informants of Telecom A, RI tools such as PDM and VRT could reduce uncertainty risks (e.g., hardware equipment breakdown). The integrated R and D and design systems (e.g., PRO/E) also assure the maneuverability and stability of the equipment improvement program in case B and C. With the help of Cimatron, UGII and NC programming system, case B optimized its R and D structure and realized the real-time synchronization of equipment information and its virtual condition.

RI's effect on PMI: RI's functions are significant in the R and D and design department, while the PMI are mainly used in the production process. However, the effect of RI on PMI cannot be denied as the virtualization tools such as virtual reality technique can simulate the probability of new PMI. Telecom A created a cloud service platform to help develop TD-SCDMA, UMTS from different level and the platform has played an important role in forming a new process innovation mode.

Production informatization's effect on the process innovation: Researchers have examined a wide range of advanced manufacturing technologies including Computer Aided Manufacturing (CAM) and Computer Numerically Controlled (CNC) machines as potential sources of process innovation (Nair and Swink, 2007).

PI's effect on PTI: Most PTI are used to produce new product. Telecom A redesigned its production system with the help of Fraunhofer-Gesellschaft in German to online-monitor, control and diagnose the application of its process technology. The information systems, such as Computer Integrated Manufacturing Systems (CIMS) and

Manufacturing Execution System (MES), were put into use in Appliances B since, 2000. Such production informatization was found to be effective in improving the process technology innovation in real time. Similar situation also occurs in case C-case D.

PI's effect on PEI: Case B, C and D are better in adopting PI to improve PEI. Take Equipment D for instance, PI systems such as CAPP improved the processing efficiency of the X shaped blade of the water turbine to 79% with a weight error no more than 2.1%. The CIMS in Equipment D combines the production data management, quality plan and control and other subsystems comprehensively, forming an integrative development of both product design and equipment/tool improvement. Besides, Equipment D also rechecked the components of the water turbine with PI means.

PI's effect on PMI: The PMI plays an important role in the manufacturing department and PI systems are closely related to PMI. The Integrated Supply Chain Management (ISCM) was applied by Telecom A in the optimization of the process management.

Management informatization's effect on the process innovation: Management informatization includes the use of Transaction Processing System (TPS), Decision Support System (DSS), Office Automation (OA), Enterprise Resource Planning (ERP), etc.

MI's effect on PTI: MI can influence the procedure of PTI by controlling and sharing the ideas and R and D information. Desktop cloud, an upgraded cloud computing mode, has been implemented by Telecom A since, 2009. The knowledge sharing and communicating through the desktop cloud affects Telecom A's R and D on process technology to some extent. The use of MI reduces resources and protects innovation data effectively.

MI's effect on PEI: Compared with Telecom A, Appliances B's cloud computing ability is still in developing. With integrated supply chain management platform, Appliances B employs unified management through encoding information on resources such as staff, product, equipment, storage, etc. Equipment information, including the norms, parameters, processing cycle and depreciation, can be processed by the management information system and be used to work out an optimum equipment innovation plan. Unexpected equipment shut down can be quickly responded by the IS functions of message passing and response as well.

MI's effect on PMI: By using management information system, Equipment D is able to make multi-objective optimization decision and real-time management on manufacturing equipments. With Digital Electric-Hydraulic (DEH) control system, Equipment D simplified the debugging work of a motor and prolonged the motor's service life.

Based on the above analysis and discussion, management informatization has played an important role for the long-run market performance in manufacturing enterprises.

Business informatization's effect on the process innovation: IT and IS used in BI mainly include Supplier Relationship Management (SRM), Customer Relationship Management (CRM), Supply Chain Management (SCM), etc.

BI's effect on PTI: It is widely believed that the establishment of interoperability of the IS of organizations with those of its collaborators (e.g., customers, suppliers and business partners) can generate significant business value and learn how their customers use their products and services (Awazu *et al.*, 2009; Loukis and Charalabidis, 2013). Appliances B invites suppliers to join in its front end design through its business network platform. And the appliance B's R and D network over the world accelerated the speed of its cooperative research and development in the field of refrigeration technique, integrated circuit, etc. For better process technology, General equipment C built a business cooperation platform to unite its suppliers, final users and cooperative partner (e.g., Hitachi and GE). Mechanical positioning monitoring technology is applied in General equipment C's product based on the software engineering. Web service, the Internet of Things and characteristics of the mechanical products to monitor the operational situation and its location.

BI's effect on PEI: The operation of manufacturing enterprises is not separated from outside; it interacts with the exterior environment (Bi *et al.*, 2012). The four cases all built their own integrated networked platforms. In case D, the enterprise builds a platform for the collaborative design and manufacturing of the power-generation equipment. And the platform of D also integrates the related business application systems with data resources. Besides, Equipment D also implements the collaborative equipment redesign with its partners and the implementation improves the power-generating equipment on the advice of its partners.

BI's effect on PMI: Kaufmann and Todtling (2001) and Becke and Dietz (2004) pointed out the importance of R and D cooperation. In their viewpoint, the construction of interorganizational networks is of great significance for the process innovation in manufacturing industries. The situation in the four cases agrees with their findings. Though the EB, CRM and SCM have little apparent direct effect on PMI, the information of case A-case D has shown the fact as follows: BI can affect the process management after digesting and absorbing the information and ideas that gathered from clients, suppliers and dealers.

The analyses presented above shows that BI's effects on process innovation are mostly indirect.

HOW PROCESS INNOVATION AFFECT INFORMATIZATION IN MANUFACTURING ENTERPRISES

Process technology innovation's effect on the informatization: PTI can be defined as the development of new product designing technology, manufacturing technologies and other related technologies (Nair and Swink, 2007).

PTI's effect on RI and PI: Companies can acquire innovative ideas and technologies for new products/services at different levels of maturity and from different types of intermediaries (Nambisan *et al.*, 2012). In order to enhance the accuracy and creativity of the process technology knowledge, the selected cases strengthened the application of RI such as CAD, CAPP, PDM, etc. Take case C for instance, uncertainty factors such as technology uncertainty and environment uncertainty impelled General equipment C to take in simulation technique and virtualization technology to carry out the simulation and virtualization of the process technology. For instant information sharing within R and D department, both General equipment C and Equipment D applied the CIMS and combined 3D design, data, quality and control systems. Affected by the divergence of process technology in different manufacturing industries, IT/IS of PI has to be adjusted in accordance with the process technology standard. In case C, the company embedded the workshop into the PI system. Besides, Equipment D developed aerodynamic/hydrodynamic analysis software CFX-TASC flow according to its needs of innovation, establishing a hydraulic design system based on liquid computing.

PTI's effect on MI and BI: When it comes to MI, little evidence on how PTI affect MI has been found in the six

cases as the MI systems being used such as ERP are bought from IT ventures and are preset. Those management IT/IS are mainly related to the decision making and enterprise operation management. Although the effect of PTI on BI is not so obvious and direct, the cooperation need for product innovation and PTI stimulates manufacturing enterprises' management on information and cooperation network and helps to transform their market and cooperation network. In case B, the demand to meet the R and D cooperation and collect PTI ideas coming out of sources from clients, partners and competitors has helped Appliances B's construction of the Sales and Operations Planning (S and OP) and Global Value System (GVS).

Consequently, the cases discussed above demonstrate that the PTI has direct impact on RI and PI and may have indirect impact on MI and BI.

Process equipment innovation's effect on the informatization: PEI is an important part of process innovation (Nair and Swink, 2007). It typically involves the use of specific change tools, machines and other equipments in manufacturing.

PEI's effect on RI and PI: The duplication of equipment between development and manufacturing facilities are all significant in improving performance in introducing new technologies (Hatch and Mowery, 1998). In case A, the process detection device created by Telecom A detects the main board information and gives feedback to Baseboard Management Controller (BMC), forming an interaction between the informatization and process equipment. The combination of robot equipments and manufacturing technology will trigger changes of IT in R and D and manufacturing process. Take General equipment C for instance, C's equipments and tools in the robotization in modern integrated manufacturing applications pushed the upgrade and replacement of both R and D IT and manufacturing IT/IS. The import and improvements of the Numerical Control (NC) machines also drive the production informatization directly.

PEI's effect on MI and BI: The normal and abnormal states of the process equipments concern the enterprises' performance and are connected with management activities. As for BI, although the introduction decision of new process equipments might be influenced by market change and client demand, the PEI's effect on BI is hard to observe.

Process management innovation's effect on the informatization: PMI includes the optimization of process management mode, the process reorganization, etc.

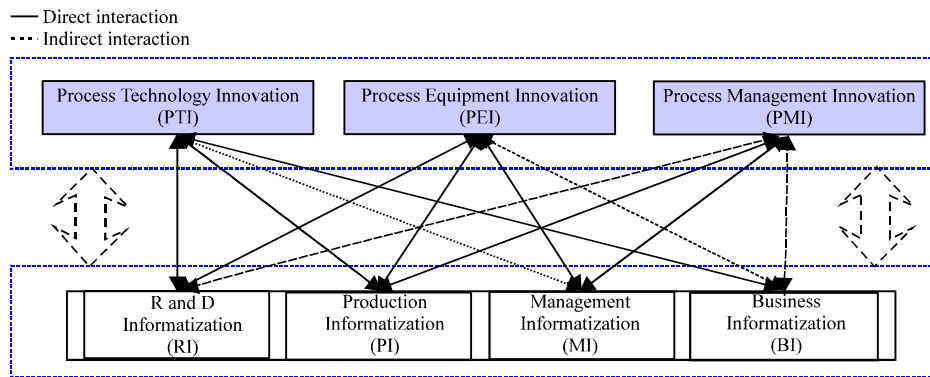


Fig. 1: The two-way relationship model of the informatization and process innovation

PMI’s effect on RI and PI: According to the face to face interviews, the PMI’s effect on PI is more obvious than its effect on RI. As the process management means a lot in the production department, the optimization of the process innovation links with manufacturing information systems and the computerized production line, therefore, the process change leads to the adjustment of the PI systems. In order to debug the working condition of mechanical processing, Telecom A bought an integrated management system from IBM and it accelerated Telecom A’s management informatization upgrading.

PMI’s effect on MI and BI: Driven by the demand of process knowledge management, Telecom A integrated the hardware equipment with cloud management and distributed storage engine. In case B, an effective PMI drives the combination of Appliances B’s virtual network (linkage with users by internet) and real network (logistics and market network), pushing the information flow, logistics flow and capital flow. The process management requires enterprises bring in advanced Management Information System (MIS) to achieve an automatic process controlling.

According to the above analysis and discussion, the dynamic and complicity characteristics of the process management improved the standard of R and D information technology. The cross management of the process acquires the participation of both PI and MI.

RESULTS

The results of the analyses above are summarized as the two-way relationship model of the informatization and process innovation. The model can be seen in Fig. 1 illustrates the direct or indirect relationship between the informatization and process innovation.

CONCLUSION

This study explores how informatization and process innovation interact with each other in manufacturing enterprises on the basis of 4 cases’ information. Such research provides an overview of the two-way relationship between the informatization construction and process innovation development. The research results can provide instruction for managers and top management team members in manufacturing enterprises on how to reinforce the coordination between the informatization and process innovation.

First, RI has direct interaction with PTI and PEI and has a less direct interaction with PMI. Second, the interaction between the PI and process innovation is testified in the case study. With the application of PI, the development of PTI, PEI and PMI could be implemented with better effectiveness. Third, comparing with the interaction between MI and PTI, the MI-PEI interaction and the MI-PMI interaction are found to be relatively direct. The impact of PTI on MI in Chinese manufacturing enterprises still needs to be strengthened. Fourth, BI has a comparatively indirect interaction with process innovation.

Like all research, this research has its limitations. Although informatization and process innovation showed their two-way relationship in the case study, empirical studies based on data with large sample size are needed for further argument.

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