Recognition of Process Innovation Risk Factors in Manufacturing Enterprise under the Circumstance of Informatization

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Abstract
Process innovation is an important way for manufacturing enterprises to improve labor productivity and lower the cost of innovation. However, Process innovation in manufacturing enterprises under the circumstance of informatization is a risk activity that is full of uncertainty and complexity. Therefore, Process innovation risk recognition and management under the circumstance of informatization is the necessary condition to implement process innovation successfully. Based on the analysis of the process that manufacturing enterprises use informatization to conduct process innovation, the evaluation indicator system of process innovation risk factors in manufacturing enterprise under the circumstance of informatization is established. Group eigenvalue method (GEM) is adopted to recognize the importance of process innovation risk factors, and the evaluation system of process innovation risk factors is established, which provides scientific theoretical basis and extensive application prospect for warning and decision-making of process innovation risk.
Key words: INFORMATIZATION, PROCESS INNOVATION, RISK FACTORS, GROUP EIGENVALUE METHOD

1. Introduction

Process innovation is always considered as an important way of promoting technology level and product innovation ability of manufacturing enterprises, which is also a necessary approach for manufacturing enterprises to enhance core competitiveness [1]. With the exploitation of information resources and the application of IT, manufacturing enterprises begin to use IT to develop new process or improve conditional process, which on one hand helps manufacturing enterprises improve the process innovation efficiency and reduce the cost of manufacture, on the other hand advances the process innovation ability, and thus increases the competitive advantage of manufacturing enterprises. However, process innovation under the circumstance of informatization is a kind of high risk activity that is affected by various factors. If the enterprises engaged in process innovation lacking enough knowledge of those influence factors or lacking strong power to control those factors, enterprises may get a variety of loss instead of achieving anticipated goal [2]. Consequently, it's a

significant and emergency task for manufacturing enterprises to identify and then prevent process innovation risks under the circumstance of informatization.

Schumpeter put forward the five types of innovation, and "the new production technology method" is called process innovation. Oslo Manual published by the Organization for Economic Cooperation and Development (OECD) in 1997 are the most widely recognized for giving the definition of process innovation. The survey defines process innovation as "the use of new or significantly improved technology for production or the supply of goods and services[3]. Ren presents some of the main drivers and barriers to activities aimed at improving existing processes and developing new processes in the petrochemical industry [4]. From resource-based view, Tarafdar explored the influence of information systems competencies on process innovation, and considered that Business-IS Linkages can differentially affect the conception, development and implementation of process innovations [5]. Srivardhana etc has examined the relationship between ERP systems and innovation from a knowledge-based perspective, and highlighted ERP systems present dialectical contradictions, which enabling and constraining process innovation[6] . Hervas-Oliver etc has take process innovation as a growth strategy for SMEs, enriching and complementing the well-researched debate about product innovation [7].

Literature has appeared recently that has relevance to furthering the exploring of process innovation, such as process innovation drivers and barriers, process innovation strategy, process innovation organization. However, there is little specific and in-depth research on process innovation risk. Based on a number of literature of recent years, a model of process innovation risk factors of manufacturing enterprise under the circumstance of informatization is built up, and then group eigenvalue method (GEM) is applied to identify key risk factors of process innovation, so as to provide scientific method and fresh approach for manufacturing enterprise to measure and evaluate the process innovation factors under the circumstance of informatization.

2. Process Innovation Risk Factors Evaluation Indicator Design in Manufacturing Enterprises under the Circumstance of Informatization

Process innovation risk refers to the probability that process innovation fail to reach its goal because of the uncertainty of external environment or the complexity of the process innovation project as well as the limitation of the innovator's novel ability. As the development of informatization, manufacturing enterprises are faced with new technical risk and environmental risk and management risk [8]. Consequently, how to measure the risk of process innovation risk becomes one of the important preconditions for the manufacturing enterprises to do process innovation under this new situation.

2.1 Basic Factor Analysis

Under the condition of informatization, the risk of process innovation in manufacturing enterprise largely depends on the government, market, economic, competitors, etc, which constitutes the environment risk of process innovation under the condition of informatization. As the application of information technology and the utilization of information resources, the process innovation risk in manufacturing enterprise includes the risk of process innovation environment, information technology introduction, integration of information technology and process technology, process innovation under the condition of informatization.

The relevant risk of every link has an impact on the implementation of process innovation. (1) Process innovation environment risk, such as instability of domestic and foreign economic situation, threaten of competitor, has a direct impact on process innovation power. Process innovation environment risk is precondition of process innovation, (2) Information technology cognitive risk and risk of choosing digital equipment in the introduction of information technology have important impact on the implementation of process innovation, which is essential to process innovation [9], (3) The integration of information technology and process technology is affected by the absence risk of training on leaders and staff before integration risk that IT can't meet the needs of process innovation, and determine the performance of process innovation, (4) The process innovation under the condition of

informatization is affected by the risk of process innovation planning and risk of process technology maturity, etc. which determines whether the manufacturing enterprise can successfully transform technical advantage and knowledge advantage into competitive advantage through the process innovation.

2.2 Evaluation Indicator Construction

Referring on the conclusion of plenty literature and the process that manufacturing enterprises using informatization to conduct innovation process, this article consider the risk of process innovation in manufacturing enterprises under informatization include process innovation environment risk, IT introduce risk, information technology and process technology integration risk, and process innovation risk [10-13]. The process innovation environment risk includes change of natural environment, instability of domestic and foreign economic situation, government intervention, instability of market demand adverse change, instability of market supply, threat of competitor; IT introduce risk include information technology cognitive risk, overall planning risk of adoption of information technology, risk of choosing software service providers, risk of choosing digital equipment, and risk of information security operation; information technology and process technology integration risk include absence risk of training the leaders and staff before integration, the risk that IT can't meet the needs of process innovation, risk of coordinating information technology and process technology, risk caused by lack of Management experience; process innovation risk include risk of process innovation planning, risk of process innovation tool selection, risk of process technology maturity, risk of funds operational allocation, risk of process innovation time schedule, risk of intellectual property protection and risk of expected goal. Based on this, As figure 1 shows, this article constructs an indicator system of process innovation risk factors in manufacturing enterprise under informatization condition, which including four secondary indicators and 22 three-level indicators.

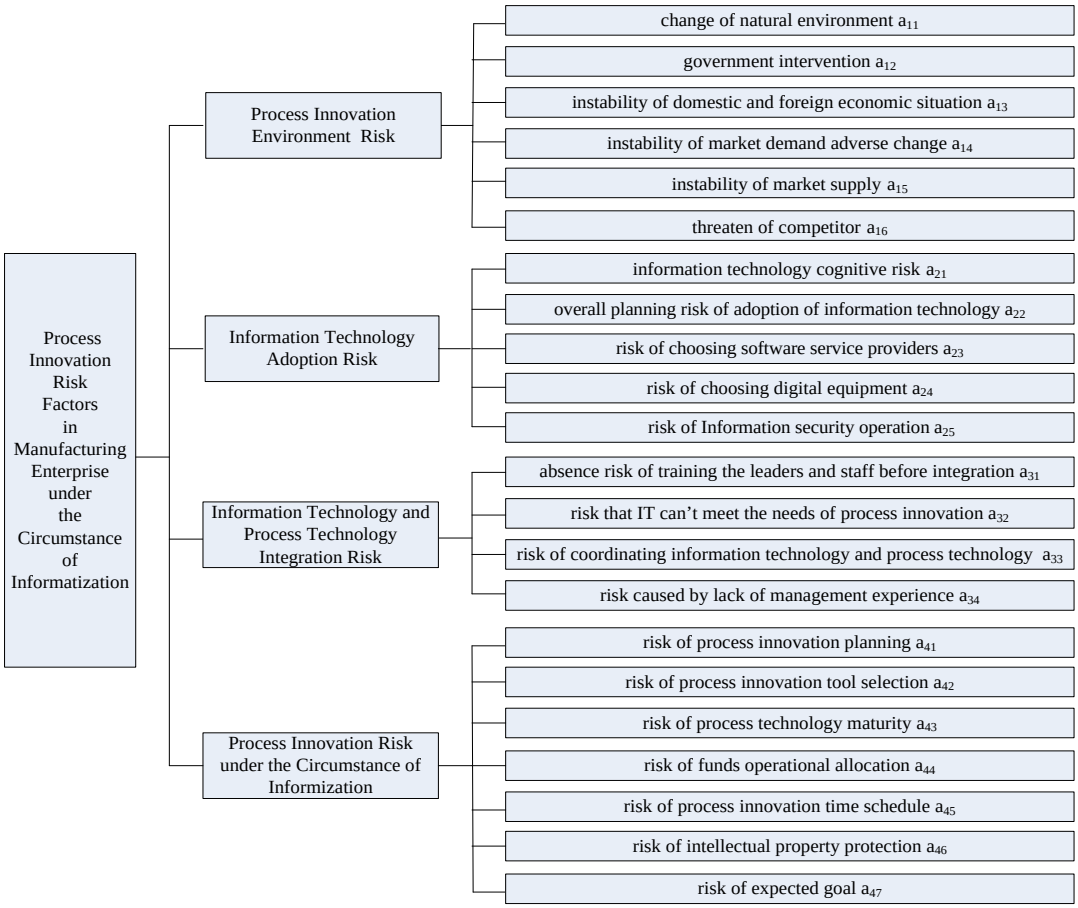

Figure 1. Process Innovation Risk Factor Indicator System

3. Recognition of Process Innovation Risk Factors in Manufacturing Enterprises under the Circumstance of Informatization

3.1 Theory Analysis of Recognition of Process Innovation Risk Factors

The research of process innovation risk factor indicator of manufacturing enterprise under the condition of informationization is still in the exploring stage, the existing research mainly apply ANP, AHP or grey relational analysis method. Nevertheless, as the process innovation risk factor indicator of manufacturing enterprise under the condition of informationization is plenty and cover widely coverage, the methods mentioned above cannot identify the weight of indicator under criterion layer effectively, therefore we can't accurately discard the subordinate indicator and keep effective information [14]. To solve this problem, this paper applies group eigenvalue method to evaluate the multiple process innovation risk factor indicator of manufacturing enterprise under the condition of informationization.

3.1.1 Group Eigenvalue Method Overview

Group eigenvalue method is a new method that group G makes decision on multiple judged targets. According to the weight of experts in group decision-making, it comprehensively calculates the advice of expert. Evaluation points of ideal expert calculated out by this method is sequencing of multiple target. This method requires experts directly give scores to the judged target, and then squares transposed score matrix recorded as matrix F. The corresponding eigenvector of maximum characteristic root of matrix F is the optimal decision conclusion [15]. Compared with AHP method, group eigenvalue method is better than the Saaty judgment matrix method used more commonly at present eigenvalue, and more easily to implement. Only the experts score in accordance with the customary manner, the optimal seqencing results of target conducted by group can be taken, avoiding the judgment matrix of AHP is more prone to product successively inconsistency of target.

3.1.2 Ideal Experts' Model

Expert group decision making system G which is composed of $S_1,S_2,\ldots,S_m$, evaluates object of $B_1,B_2,\ldots, B_n$. Let x_{ij} be the value of evaluated object B_j evaluated by the expert S_i (i = 1, . . . ,m; j = 1, . . . , n). A higher value of x_{ij} indicates a better of object of B_j. The scores of S_i and group G comprise n dimensional column vector and m×nth order matrix.

$$X_i = \left(x_{i1}, x_{i2}, \ldots x_{in}\right)^T \in E^n$$

$$X_i = \left(x_{ij}\right)_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

They are the conclusion made by experts and groups in the process of the decision, on behalf of the estimated value of evaluated object. Score vector of ideal expert is $x_*(x_{*1}, x_{*2},\ldots, x_{*n})^T \in E^n$. High levels of experts are always employed to participate in evaluating, so the definition of ideal experts is the experts who has the highest consistency with expert group G in understanding the evaluated object, namely the decision conclusion of S_* is completely consistent with G, and have the minimum differences with the individual experts.

Definition: If the sum of the angles of an expert's score vector between others' is the minimizing, this expert is called the group's ideal (optimal) expert.

Based on the definition above, X is the vector that meets the function $f = \sum_{i=1}^{m} (b^T x_i)^2$ can achieve the maximun,can $\vee b = \left(b_1, b_2, \ldots b_n\right) \in E^n$, consider $\|b\| = 1$, namely $\max \sum_{i=1}^{m} \left(b^T x_j\right)^2 = \sum_{i=1}^{m} \left(x^T{}_* x_*\right)^2 = 1$, where x_* $\underset{\|b\|=1}{b\in E}$ is the total score that G gives the evaluated object.

3.1.3 Related Theorem Solution

Theorem 1. $b\forall E^n$, $\max\limits_{b\in E^n} \sum\limits_{i=1}^{m} \left(b^T x_i\right)^2 = \rho_{\max}$,where $\rho_{\max}$ is maximum eigenvalue of matrix $F=X^TX$

Theorem2. Consider A is m×nth order matrix, B is n×mth order matrix, and then AB has the same (including multiplicity) nonzero eigenvalue with BA.

Theorem3. Consider a_0 is the corresponding eigenvector of maximum characteristic root of matrix X^TX, and $\|a_0\|$

=1, and then $X^Ta=KX_*$, namely a_0 is the weight vector of m experts.

3.1.4 Single and Double Root Process

If the maximum characteristic root is simple root, then the corresponding eigenvector gives an optimal decision; If the maximum characteristic root is multiple root and calculates the feature vector space, then the evaluation object corresponded to the feature vector space is considered equally important, namely coordinate ranking, and other evaluated object is ranked by the eigenvectors corresponded with the second largest characteristic root [15].

3.2 Empirical Analysis of Recognition of Process innovation risk factors

In order to evaluate master-slave sort and important degree of process innovation risk factors in manufacturing enterprise under the circumstance of informatization, according to the established of indicator system, investigate the experts in relevant field randomly by the questionnaire. Questionnaire is shown in Table 1. According to the key indicator that reflects process innovation risk factors in manufacturing enterprise under the circumstance of informatization, the paper designs five levels that is from “very obvious” to “not obvious”, corresponded from 5 to 1. Take the indicator of process innovation environment risk as an example, Score sheets are seen in Table 1.

1) Initial score matrix $X_{22\times6}$ of process innovation risk factors is calculated by table 1, $F=X^T\cdot X$.

$$F=\begin{bmatrix} 214 & 249 & 239 & 212 & 219 & 257 \\ 249 & 325 & 310 & 279 & 286 & 339 \\ 239 & 310 & 317 & 277 & 284 & 328 \\ 212 & 279 & 277 & 262 & 259 & 306 \\ 219 & 286 & 284 & 259 & 278 & 313 \\ 257 & 339 & 328 & 306 & 313 & 378 \end{bmatrix}$$

Table 1. Experts rating scale of process innovation environment risk

	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}		a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
S_1	2	3	3	3	4	4	S_{12}	2	4	3	3	3	5
S_2	2	3	2	4	3	4	S_{13}	2	3	4	3	3	4
S_3	4	4	5	5	5	5	S_{14}	2	3	3	3	2	5
S_4	2	3	4	4	4	4	S_{15}	4	3	2	2	3	4
S_5	4	4	5	3	3	3	S_{16}	2	4	4	2	4	3
S_6	3	4	4	3	4	5	S_{17}	2	4	4	3	5	4
S_7	4	3	5	3	3	3	S_{18}	3	4	5	5	4	4
S_8	5	4	2	3	4	4	S_{19}	5	5	4	3	3	3
S_9	2	5	4	4	3	4	S_{20}	5	5	4	3	2	4
S_{10}	2	3	3	4	4	5	S_{21}	2	4	3	4	2	4

2) Using MATLAB software to calculate the maximum characteristic root $\rho_{\max}$ of F

$$\rho_{\max}=\{0.3347,0.432,0.424,0.3856,0.3961,0.4647\}^T$$

3) Calculate the corresponding eigenvector of maximum characteristic root of matrix F and standardized, namely B

$$B=\{0.137335,0.17726,0.173977,0.158221,0.162529,0.190677\}^T$$

Vector B is ranking of relative importance between various factors, Through the selection of key elements, remove the factors whose relative importance is less than 0.9 by 1/6. The relative importance of a_{11} is 0.137335<0.15, remove the factor; the relative importance of a_{12} is 0.17726>0.15, retain the factor; the relative importance of a_{13} is 0.173977>0.15, retain the factor; the relative importance of a_{14} is 0.158221>0.15, retain the factor; the relative importance of a_{15} is 0.162529>0.15, retain the factor; the relative importance of a_{16} is 0.190677>0.15, retain the factor. Remove a_{11} and get new score matrix.

4) Calculate the relative importance between various factors in the new score matrix F'.

$$F' = \begin{bmatrix} 325 & 310 & 279 & 286 & 339 \\ 310 & 317 & 277 & 284 & 328 \\ 279 & 277 & 262 & 259 & 306 \\ 286 & 284 & 259 & 278 & 313 \\ 339 & 328 & 306 & 313 & 378 \end{bmatrix}$$

$$\rho_{\max}{}' = \{0.4567, 0.4496, 0.4101, 0.421, 0.4939\}$$

$$B' = \{0.204679, 0.201497, 0.183794, 0.188679, 0.221351\}$$

Remove the factors whose relative importance is less than 0.9 by 1/5. The relative importance of a_{12} is 0.204679>0.18, retain the factor; the relative importance of a_{13} is 0.201497>0.18, retain the factor; the relative importance of a_{14} is 0.183794>0.18, retain the factor; the relative importance of a_{15} is 0.188679>0.18, retain the factor; the relative importance of a_{16} is 0.221351>0.18, retain the factor. Consequently every factor conforms to the requirements.

The results show that in the process of recognition of key factors, Change of natural environment a_{11} and risk of process innovation time schedule a_{45} are not the key elements that effect process innovation in manufacturing enterprise under the circumstance of informatization.

3.3 Process Innovation Risk Key Indicator Analysis in Manufacturing Enterprise under the Circumstance of Informatization

3.3.1 Process Innovation Environment Risk

The forced intervention that the government may take such as the price intervention, market intervention, etc would affect the process innovation of manufacturing enterprises. In addition, the unstable economic situation at home and abroad, such as depressed PMI (purchasing managers indicator), deteriorative economic situation, rising unemployment, fluctuating product price caused by international economic crisis, bring about adverse conditions for the process innovation of manufacturing enterprises. To varying degrees, the uncertain market demands, unstable supply of raw materials, labor force and energy sources, impact from imported product, competitive threat such as the technology advanced enterprise's control to the market form the process innovation risk of manufacturing enterprise under the condition of information. Thus it can be seen that screened indicators are more reliable.

3.3.2 Information Technology Adoption Risk

The information technology cognitive risk in manufacturing enterprises is due to the wrong concept of information technology, overstating of the IT impact, underestimate of IT hardware cost, and financial burden caused by over budget[16]. The overall planning risk of adoption of information technology in manufacturing enterprises is usually because that every department just introduce information technology according to the needs of itself without thinking about the overall optimal principle, which often leads to condition of information island, waste of investment, low level application, multiple data source and data corruption[17]. There is also risk when choosing of software service providers. In the course of information technology introduction, information technology should update continuously so as to adapt the development of enterprise, and if the bankruptcy or collapse of software service providers lead to software upgrade service interruption, it would be obstacle for the informatization of enterprise[18]. There is a risk in choosing digital equipment includes, the digital equipment can't play the role of assessibility if the utilization rate of chosen equipment is too low. There also exit some risk in information security operation, risks such as loss of data, security of network transmission and so on may increase the uncertainty of process innovation. In general, these indicators are reasonable to define the information technology adaption risk.

3.3.3 Information Technology and Process Technology Integration Risk

The insufficient training for manufacturing enterprise leaders and staff before the integration of information technology and process technology may result in some risk. Sometimes the application of information technology can't meet the demand of manufacturing enterprise that proceeding process innovation, information technology is always used as a tool of data search instead of data mining and processing, little data is transformed to process innovation resource, and this would affect the integration of information and process technology. The failure of integration between information technology and process technology can be caused by the risk of mismatching of information technology and process

technology, lack of management experience on information technology and process technology. Consequently, the above indicator can reflect the risk of process innovation under the condition of informatization effectively and can be widely accepted by experts.

3.3.4 Process Innovation Risk under the Circumstance of Informatization

The risk of process innovation planning, such as the definition of successful standard of process innovation during the planning period, the inaccurate evaluate on the cost of process innovation, has an impact on process innovation in manufacturing enterprises. In the course of process innovation in manufacturing enterprises, the tools of process innovation include information technology and communication technology etc. the selection of process innovation tools affects the efficiency of process innovation. Process technology maturity plays the important role in process innovation. The excessive dependence on the scarce system and early-warning information system lead to lack of elasticity in process innovation. The risk of process innovation, such as the uncertainty of process technology life cycle and the product condition hardly meets the requirements of the process innovation, restricts the development of manufacturing enterprises. Bad allocation of operational funds will reduce the speed of innovation process. Long time of manufacturing enterprise process innovation tends to make technology innovation achievement lack of progress, and lose market opportunities. Poor protection of intellectual property leads to new process technology accessed by the rivals. The advance investment in process innovation will form bubble. The risk of expected goal in process innovation such as the products quality of process innovation and the cost of process innovation can't achieve the standard level, determines the results of process innovation.

4. Conclusions

Under the circumstance of informatization, the risk of process innovation in manufacturing enterprises is full of complexity and uncertainty. Based on the course of process innovation by using information in manufacturing enterprises, the paper has put forward the risk factors of process innovation under the circumstance of informatization, and has identified the key risk factors of process innovation under the circumstance of informatization by using group eigenvalue method. The result indicates that the group eigenvalue method is good at solving the problem of multiple indicator selection, and making the indicator more scientific, comprehensive and valid. On the other hand, this method has provided a new approach to early-warning and decision for process innovation risk under the condition of informatization, thus has a scientific theoretical basis and broad application prospect.

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