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Study on Quality control of CoPS Innovation Based on Quality Chain and Quality House

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Abstract

With the development of the science and technology, Complex Product and System (CoPS) plays a more important role in modern economy and society. This paper aims at the problem of quality control in the CoPS innovation. Through studying the CoPS characteristics and different innovation mode from the mass production, we established the quality chain model. The model is a process network in which nodes are consist of the suppliers, manufacturers and customers etc. the lines between the nodes is process of quality transmission. Compared with the process model of normal innovation, the process added four steps (task decomposition, analysis of knowledge demand, outsourcing selection and system integration) which reflect the Complexity of CoPS innovation. Traditional processes such as trial-manufacture and R&D process are involved in the module development. Despite that some scholars have a profound interest in the process of quality transfer in he quality chain and put forward some method solve quality problem of CoPS innovation, up to now little suitable and quantization method is presented. In the paper, quality houses are adopted to deal with the relation of quality chain nodes and interpret the process of quality transfer. Quality requests of one node are converted the technique indexes of another node in the quality house. At last an example is given to illustrate that this approach can improve quality control level more than the traditional statistical process control method and effectively reach quality management of CoPS innovation.

Index Terms: Quality Chain; Complex Product System; Quality House

1. Introduction

CoPS refer to the large products or infrastructures with high technology content, small mass customization and high integration, for example high-speed train, large communication system and airborne weapon system etc[1]. Processes of CoPS innovation involve many domains such as mechanism and sensor technique, information processing technique, computer control technique and control theory. Therefore CoPS innovation success can facilitate technological progress and industrial upgrading in related domestic industries and enhance the national competitiveness. Miller and Hobday[2] found that the value of CoPS innovation

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accounted for 11% percent of the Uk GDP by investigating a variety of products data. Kash[3] pointed out 30 most valuable products in the export goods 43 percents of 30 most valuable products in the export goods involved complex technology in 1970. And this ratio is 84% in 1996. China has integrated global market competition. CoPS development can improve our overall national strength and competitiveness of products.

At present, a few scholars have studied the problems of CoPS innovation. Andrew Davis mainly researched the CoPS innovation processes of the telecommunication enterprise and explored the role of government in these CoPS innovation. Garm and Ammon J.Salter aimed at the processes and methods of project management in the CoPS innovation such as organization form based on project, knowledge management based on project and team management based in project etc. Kash and Rycroft come up with three modes of CoPS innovation, i.e. mode of transformational change, normal mode and mode of leaping development. Kash and Rycroft pay attention to the change of the core competence, organizational learning, path dependence and environment selection in the different modes.

In light of the above studies, few scholars are concerned with the quality control problems of CoPS innovation. However quality control is the key step of CoPS innovation success or no. Almost all failing cases are relevant to the imperfect quality control. So far, there is not a perfect method of quality control to be used in CoPS innovation. Quality control of the existing CoPS innovation refers to the modes of large-scale manufacturing products. Quality control of large-scale product innovation is relatively mature. But compared with large scale products, CoPS are markedly different in the product characteristics, production characteristics, innovation process, market characteristics etc. Therefore, many theories of quality control applied by large scale products can not be directly transplanted into the CoPS innovation. In this paper, we adopted quality chain to study the quality control problem of CoPS innovation and build the network model of quality chain. Nodes are consist of the suppliers, manufacturers and customers etc. the lines between the nodes is process of quality transmission. Quality house is used to handle the process of quality transfer among the nodes. This approach can improve the quality level of CoPS innovation as well as effectively cutting into innovation cost.

2. Characteristic of COPS Innovation

Process of CoPS innovation is a special innovation process which is based on the normal innovation but have different characteristic with normal innovation.

2.1. Complexity

As to the complexity of CoPS innovation, it is not only embodied in the integral structure, but also obviously displayed on the component parts. CoPS contain a number of customized cell and subsystem. They are very complex for themselves which contain some inner cell. Relations between them are also complex. Control elements are used to deal with these relations. A microscopic change of component parts is likely cause the system breakdown. In addition, technical compositions of CoPS innovation are complex which is unconcerned with the broad knowledge range such as, computer, electron, machinery, even chemistry and physics etc.

2.2. Weakened function of market and manufacture

CoPS innovation is mostly small batch, limited number of transactions and limited competition under government. CoPS innovation has shaped when the whole R&D process finished. There are not individual processes of manufacturing and expanded reproduction. These processes have melted into R&D process. In most cases, CoPS development is to meet customer demands. So it is classic customized product which need not market expansion.

2.3. Strong interaction of core company and suppliers and customers

To be different from normal innovation which customers' requests are transferred though the information of market transaction, customer directly participate the whole process of CoPS innovation. Some systems, for example intelligent Building, must be improved continuously in light of the customers' requests. Furthermore, suppliers are not merely the companies which supply the core company with raw materials and mechanical equipments. They are pestered to join in the some processes of CoPS innovation. And even the key suppliers must participate in the whole processes of CoPS innovation.

3. Quality Chain Model of CoPS Innovation

Quality control methods of CoPS innovation are based on the process of CoPS innovation. According to the above CoPS characteristic, we set up the process model of CoPS innovation shown in the Fig 1. Compared with the process model of normal innovation, the process model add four steps (task decomposition, analysis of knowledge demand, outsourcing selection and system integration) which reflect the complexity of CoPS innovation. Traditional processes such as trial-manufacture and R&D process are involved in the module development.

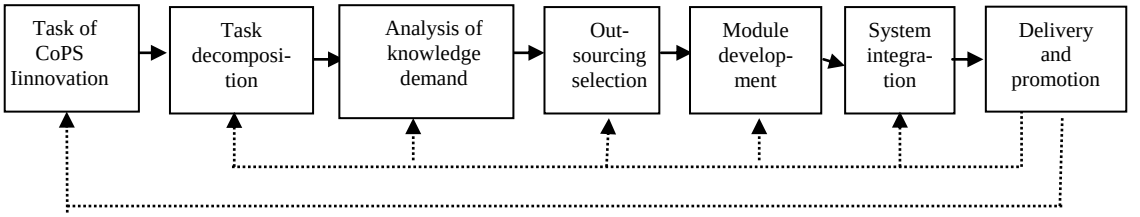

Fig. 1. Process model of CoPS innovation

Based on the process model, Quality chain model is interposed of CoPS innovation. It has three dimensions structure. The first is the lateral quality management in nodes settings which is based on the supply chain of CoPS innovation. The second is the inner longitudinal quality management which is quality policy including quality planning, quality management level and quality improvements etc. The last expresses the relation among the nodes. The nodes refer to the external cell of the core business related with CoPS innovation such as suppliers, customers and research institute etc. quality chain model of CoPS innovation is shown in the following Fig 2.

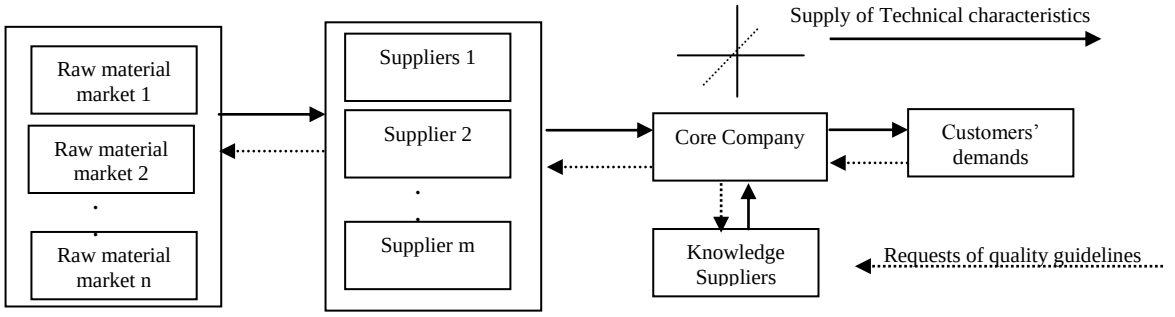

Fig. 2. Quality chain model of CoPS innovation

Nodes and nodes are linked by quality information. Quality is a set of characteristic which must satisfy the needs of user demands. Quality demands of upstream companies on downstream companies appear in a set of the Quantity quality guidelines. These guidelines deliver from downstream companies to upstream companies in accordance with the dash line direction. At the same time, upstream companies deliver information on product technology to downstream companies and attend product design in accordance with the solid line direction.

A few scholars presented some methods to study the quality delivery between nodes. R.B.XIAO adopted the advanced SCOR to set up a process model of closed loop quality chain. M.Y.SHAN used Customizable DEA model to solve the consensus problem of among nodes. These methods are only suit to the normal innovation. In the paper, we adopt advanced QFD method to handle the quality relation between nodes.

4. Quality Chain Model Base on QFD Method

QFD is a quality assurance means for new product development. Quality house is its key part. It can transfer the quality demand of customers into quality characteristic of products (technology parameter). In the quality chain of CoPS innovation, customers' requests must be converted into product technical characteristic and finally become the quality requests to all nodes by request transmission from downstream companies to upstream companies. Quality house is used to links all nodes thought mutual transformation of quality request and technical characteristic in the quality house and request transmission among two and more quality houses. The model of quality house is shown as the following Fig 3.

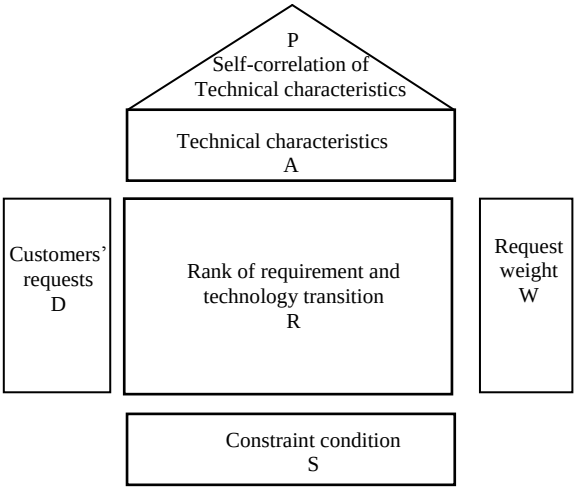

Fig. 2. The model of quality house

Let i=1, 2, … , k stand for K nodes where i represents random node. Then $Ri=[r_{i1},r_{i2},\ldots,r_{im}]$ represents the customers' requests guidelines of downstream companies to upstream companies. $Wi=[w_{i1},w_{i2},\ldots,w_{im}]$ stands for the weight of requests guidelines. $Ai=[a_{i1},a_{i2},\ldots,a_{in}]$ represents the product technical characteristics. Ri and Ai are all quantification data. $Pi=(p_{ij})_{nxn}$ stands for the self-correlations of technical characteristics where is the variation of technical characteristics guidelines j as guidelines i change one unit. p_{ij} equal to 0, positive quantity and negative quantity indicate irrelevant, positive correlation and conflicting interrelationships between guideline i and j respectively. We have:

$$D_i R_i P_i \xrightarrow{S_i} A_i \tag{1}$$

Where Si=(sij)mxn is a transfer matrix and its function is to build the relation between technical characteristic Ai of upstream companies and customers' requests Di+1of downstream companies. That is to say,

$$D_{i+1} = A_i S_i \tag{2}$$

When customers' requests of downstream companies appear disturbance, this disturbance will be transmitted to the upstream companies and be changed the demands to technical characteristic. From (1) and (2), we can get the bottom-up transfer model of customers' requests.

$$\begin{cases} A_1 = D_1 R_1 P_1 \\ A_{i+1} = A_i S_i R_{i+1} P_{i+1} \end{cases} \tag{3}$$

At the same time, we can obtain the top-down transfer model of technical characteristic. That is to say, when technical characteristic come up disturbance, this disturbance will be transferred downward and affect the customer satisfaction of downstream companies.

$$\begin{cases} D_k = A_k (P_k)^T (R_k)^T \\ D_{i-1} = D_i (S_i)^T (P_{i-1})^T (R_{i-1})^T \end{cases} \tag{4}$$

5. Model And Quality Analysis of CoPS Innovation

A communication system is taken as an example to show the quality control process by the above model. For simplicity, we suppose that quality chain is consist of a supplier and core company.

Let customers' requests guidelines of core company D_1= (d_{11}, d_{12}, d_{13}, d_{14}, d_{15}) = (validity, reliability, economy, flexibility, confidentiality). Guidelines of technical characteristic A_1= (a_{11}, a_{12}, a_{13}, a_{14}) = (bandwidth, bit rate, error rate). The above guidelines are all indicated in integer between 0 and 10 which are used to substitute for practical significance of technical parameters. In light of quality house, we give the parameters shown as the following matrixes.

$$P_1 = \begin{bmatrix} 1 & 0.334 & -0.267 \\ 0.334 & 1 & -0.139 \\ -0.267 & -0.139 & 1 \end{bmatrix} \qquad R_1 = \begin{bmatrix} 0.920 & 0.927 & -0.548 \\ 0.189 & 0.107 & -0.334 \\ -0.571 & -0.225 & -0.274 \\ 0.628 & 0.523 & 0.644 \\ 0.103 & 0.107 & 0.105 \end{bmatrix}$$

Let guidelines of customers' requests of supplier D_2= (d_{21}, d_{22}, d_{23}) = (bandwidth, bit rate, error rate). Guidelines of technical characteristic A_2= (a_{11}, a_{12}) = (material characterization, manufacturing technology).

About the same as D_1 and A_1, D_2 and A_2 are also indicated in integer between 0 and 10 which are used to substitute for practical significance of technical parameters.

$$R_2 = \begin{bmatrix} 0 & 1 \\ 1 & 1 \\ 0 & 1 \end{bmatrix} \qquad P_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Lastly, there is a conversion ratio between customers' requests of upstream company and technical characteristic of downstream company. Let transfer matrix S2:

$$S_2 = \begin{bmatrix} 0.924 & & \\ & 0.750 & \\ & & 1 \end{bmatrix}$$

The above data stands for parts bandwidth not more than 0.924 bandwidth of communication system and parts bit rate not more than 0.750 bit rate of communication system. Data 1 expresses that demand of error rate is upward delivered completely.

5.1. quality chain analysis for customers' requests disturbance of customers' requests

Customers' requests often modify with the dynamic change in distributed system environment. It is a key problem to analyze quality disturbance of nodes and provide the solution to these problems. We suppose the variation of customers' requests D_1 equal D_1= (1, 1, 1, 0, 1). Then variation of technical characteristic disturbance of upstream company is calculated and shown in the following according to (3)

$$\begin{aligned} A_1 = D_1 R_1 P_1 &= \begin{bmatrix} 1 & 1 & 1 & 0 & 1 \end{bmatrix} \\ &\begin{bmatrix} 0.920 & 0.927 & -0.548 \\ 0.189 & 0.107 & -0.334 \\ -0.571 & -0.225 & -0.274 \\ 0.628 & 0.523 & 0.644 \\ 0.103 & 0.107 & 0.105 \end{bmatrix} \begin{bmatrix} 1 & 0.334 & -0.267 \\ 0.334 & 1 & -0.139 \\ -0.267 & -0.139 & 1 \end{bmatrix} \\ &= \begin{bmatrix} 1.228 & 1.276 & -1.349 \end{bmatrix} \end{aligned}$$

$$\begin{aligned} A_2 = A_1 S_2 R_2 P_2 &= \begin{bmatrix} 1.228 & 1.276 & -1.349 \end{bmatrix} \\ &\begin{bmatrix} 0.924 & 0 & 0 \\ 0 & 0.750 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \\ &= \begin{bmatrix} 0.957 & 0.743 \end{bmatrix} \end{aligned}$$

The above results indicate that technical characteristic of Core Company are changed with bandwidth improving 1.228 units, bit rate improving 1.276 units and error rate decreasing 1.349 units when the guidelines of customers' requests would increase simultaneously in 1 unit with "validity", "reliability", "economy" and "confidentiality". At the same time grade of supplier's technical characteristic is increased 0.957 units with material characterization and 0.743 units with manufacturing technology.

5.2. Quality chain analysis for disturbance of supplier's technical characteristic

Supplier's technical characteristic often change with production conditions and raw materials in actual production. These directly influence product function and customer satisfaction. Assuming the variation of supplier's technical characteristic A2 equal A2= (1, -1), variation of customers' requests disturbance of downstream company is calculated and shown in the following according to formula (4).

$$D_2 = A_2 (P_2)^T (R_2)^T = \begin{bmatrix} 1 & -1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \end{bmatrix}$$

$$D_1 = D_2 (S_2)^T (P_1)^T (R_1)^T = \begin{bmatrix} -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.924 & 0 & 0 \\ 0 & 0.750 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0.334 & -0.267 \\ 0.334 & 1 & -0.139 \\ -0.267 & -0.139 & 1 \end{bmatrix} \begin{bmatrix} 0.920 & 0.189 & -0.571 & 0.628 & 0.103 \\ 0.927 & 0.107 & -0.225 & 0.523 & 0.107 \\ -0.548 & -0.334 & -0.274 & 0.644 & 0.105 \end{bmatrix} = \begin{bmatrix} -1.272 & -0.290 & 0.529 & -0.583 & -0.102 \end{bmatrix}$$

In light of the above results, variation of supplier's technical characteristic largely influences customers' requests. When material characterization increases 1 unit and manufacturing technology reduces 1 unit at the same time, grades of CoPS validity, reliability, flexibility, confidentiality reduce separately -1.272, -0.290, -0.583, -0.102. Only economy improves 0.529 unit. The results further show that disturbance of supplier's technical characteristic affects the all nodes of quality chain and deliver the disturbance in the up-bottom direction of quality chain.

6. Conclusion

Base on the deep analysis and study on characteristic of CoPS innovation, this paper has established process model and quality chain model of CoPS innovation. Despite that some scholars have a profound interest in quality problem of CoPS innovation, up to now little suitable and quantization method is presented. In the paper we adopt quality house to deal with the relation among nodes of quality chain and build the quality transfer model of CoPS innovation. The model shows clearly the process of quality transfer from downstream company to upstream company when customer's requests produce disturbance and from upstream company to

downstream company when technical characteristic produces disturbance. The above study can solve the quality control problem of CoPS innovation effectively.

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