Synergy Analysis of Quality Management in the Equipment Production Process

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Abstract. The equipment production process is an important link in the formation of equipment quality. As the main body of equipment quality formation, military representative institutions and manufacturing units are one of the decisive factors for the stability of equipment quality. Aiming at the coordination problems of military and local systems in the process of equipment production, this paper puts forward an "SDS coupling coordination degree model" which can measure the degree of coordination between organizations, to provide a methodological basis for the quality control of equipment production process.

Keywords: synergism · SDS-coupling coordination model · martial and local · coupling effect

1 Introduction

In the process of equipment production, military representative agencies and manufacturing units, as the main body of quality management, jointly complete equipment quality management around production factors such as "man-machine material method and environmental measurement". In this paper, the military representative office and the manufacturing unit are regarded as two interactive systems. The systems develop in coordination through the mutual coupling of constituent elements, which runs through the whole equipment production process. Therefore, straightening out the coupling relationship between the elements in the system and using the positive feedback of this relationship to enhance the synergy between subsystems is the fundamental source to improve the equipment quality and production efficiency. The key content of this paper is to ensure the equipment production quality with the level of military local cooperation.

2 Connotation of Martial and Local Coupling and Coordinated Development

In the whole life cycle of equipment, the production process is in an important stage connecting the preceding and the following [1]. It is the realization process of design results and the guarantee process of service quality. At this stage, there are many quality

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Table 1. Classification of coupling degree.

Coupling degree	Reverse	Forward	
	restrict	coordinate	synergism
Judgment basis	$1 + 1 < 2$	$1 + 1 = 2$	$1 + 1 > 2$
Coupling	$(-1, 0)$	0	(0, 1)

elements involved. Sometimes the elements will cooperate and promote each other to produce positive effects, sometimes restrict and restrict each other to produce negative effects, and sometimes offset the merits and demerits to maintain the status quo. From the perspective of system synergy theory, this interaction between elements is called "coupling", and the degree of coupling determines whether the system moves towards order or disorder at the critical time. When the system moves towards order, it is called forward coupling and vice versa [2]. In the process of equipment production, we should make the system forward coupling as much as possible, to achieve the collaborative state. Synergy can make the system change qualitatively at the critical point, from disorder to order, and turn critical out of control quality state into controllable. The synergy of the organization is reflected in the coordinated coupling of different aspects between different systems to produce a stable structure from chaos, to resist external risks and make the product quality stable and controllable.

From the perspective of collaborative development, this paper analyzes the coupling relationship between military and local and uses the coupling degree to measure it. As shown in Table 1.

When the military and local hold each other back and shoulder each other's responsibilities, the total effect of each element in the system is less than the total effect of the system, which shows the reverse coupling relationship, i.e. "$1 + 1 < 2$", which will lead to the reduction of equipment quality or production efficiency; When the military and local hold each other back and shoulder each other's responsibilities, the total effect of each element in the system is less than the total effect of the system, which shows the reverse coupling relationship, i.e. "$1 + 1 < 2$", which will lead to the reduction of equipment quality or production efficiency; When the coordination between military and local areas, the sum of the effects of each element in the system and the total effect of the system are satisfied, the effect of "$1 + 1 = 2$" will be achieved, which means that no obvious internal consumption has occurred between the elements, but no additional effect has been produced, and it is still possible to coordinate and coexist, equipment quality and production efficiency to maintain the current situation; When each element promotes positive stimulation, the sum of element effects is greater than the total effect of the system, reaching the effect of "$1 + 1 > 2$". This shows that there is a coupling and coordination effect between the military and local, the system is in an orderly state of development, and the production efficiency is constantly increasing. The core of quality control is to inhibit the generation of reverse coupling and promote the continuous formation of forwarding coupling.

It can be seen that the sound operation of the equipment production process depends on the coordination and coordination of each element between the military and local, and the degree of their coupling and coordination determines the coordination level of equipment production.

3 Establishment of Military-Local Coupling Index System

The purpose of collaborative management of the equipment production process is to reduce the reverse coupling of the system and improve the overall coupling and coordination of the system.

For both military and local systems, the method to achieve coordination is to coordinate the management level and business level of the military with the local technical level and quality inspection level, i.e. to change from the simple requirement of coordinated development within the contracting unit to the coordinated development of military and local linkage. Therefore, it is necessary to improve management efficiency by repositioning the relationship between the two parties, allocating functions reasonably and defining the limits of power and responsibility, and developing the application of new and high technology in the production process while improving staff's working ability and reducing the frequency of errors, to realize the coordinated development among management level, business level, technical level and quality inspection level to achieve the overall optimum. Therefore, the relationship between coupling coordination and collaborative development is the relationship between means and objectives. The coupling and coordination of each element are to take the collaborative development among systems as the goal. All deviations from the objectives can be controlled and regulated using coupling and coordination [3]. At the same time, the quality of personnel can be improved and the high and new technology can be effectively applied. Quality fluctuations are effectively controlled.

Due to the coupling and interactive relationship between the military and local governments, to reveal the coupling strength and coordination degree of their development, the military local coupling indicators are screened respectively according to the principles of dominance, hierarchy, dynamics and operability of indicator selection, and the analytic hierarchy process is used to determine the index weight and establish the index system [4], as shown in Table 2.

According to different functions and work priorities, the index system is constructed from four aspects: management level, business level, technical level and quality inspection level.

(1) Management level. As the main body of quality supervision, the military's management level directly affects the generation of equipment quality. Among them, planning ability, function distribution and horizontal communication ability are the main evaluation indicators of management level. The planning ability reflects the overall control of the military over the production process, the function distribution reflects the military's planning and organization ability for its personnel, and the horizontal communication ability reflects the military's self-improvement. All indicators are positive indicators.

(2) Business level. In the process of equipment production, the military's main work is to supervise, control and correct. The three indicators of understanding of production, quality control ability and risk identification ability correspond to the military's work

Table 2. Military-local coupling index system.

Subsystem	1st indexes	2nd indexes	Explain	Weight
Military	*Management level*	planning capacity	Rationality of planning and perfection of quality target program document.	0.2047
		function distribution	Rationality of allocation, clarity of responsibility interface.	0.1123
		horizontal communication ability	Listen to the opinions and suggestions of production units, and learn from and communicate with brother units.	0.3730
	Business level	understanding of production	Understanding of equipment quality requirements, management defects of the manufacturer and production capacity of the manufacturer.	0.0942
		quality control ability	Number of quality fluctuations in the same production cycle.	0.0553
		risk identification ability	Perception of changes in external environment and identification of critical value of quality fluctuation.	0.1606
Local	*Technical level*	the technical standards adopted	Categories of standards adopted. There are international general standards, national standards, industrial standards or departmental standards, and enterprise self-made.	0.1001
		the complexity of the technology used	The difficulty and complexity of technology and the difficulty and ease of implementation.	0.1706
		the content of high and new technology	Proportion of applied advanced technology.	0.1307
	Quality inspection level	quality awareness	Understanding of quality objectives and employees' contribution to the effectiveness of quality management.	0.2259
		inspection methods	The effectiveness and advanced nature of the method adopted.	0.0778
		quality improvement ability	Quality problems found and improved through quality inspection.	0.2950

content and evaluate the military's business level from different angles. Except that the quality control ability is an inverse index, other indexes are positive indexes.

(3) Technical level. The production technology level of the manufacturer is one of the decisive factors of the equipment quality. The technical standards adopted, the complexity of the technology used and the content of high and new technology are important indicators to evaluate the production technology level of the manufacturer. According to the different production demand and technical indicators, the adopted technical standards and technical complexity are different, so they are moderate indicators and the remaining indicators are positive indicators.

(4) Quality inspection level. Quality inspection runs through the key and important processes in the production process. The purpose is to realize the whole process of control of product quality and correct problems in time. This is closely related to the quality awareness, inspection methods and quality improvement ability of employees: the stronger the quality awareness of employees, the more responsible the inspection methods are, the more effective the quality improvement ability is, the more reliable the quality inspection level of the manufacturing unit is, so all indicators are positive indicators.

4 SDS-Coupling Coordination Model

To understand the coupling coordination degree between systems, the coupling coordination degree model is usually used for calculation. The coupling coordination degree model is a typical mathematical model. It is an application of Natural Science in the field of social science. It is used to measure the coupling development relationship between two or more subsystems. In the traditional coupling coordination degree model, the calculation of coupling degree only considers the effectiveness of each index in the subsystem to the total system, but in fact, there will be an interaction between each index and between the index and the subsystem, which will affect the coupling coordination degree of the system. Therefore, this paper improves the traditional coupling coordination degree model and combines the sustainable development system (SDS) coordinated development model to include the total influence of each subsystem index by other subsystems in the calculation of coupling degree, to make the calculation more scientific and reasonable. In this paper, it is called the "SDS coupling coordination degree model" [5], which calculates the coupling degree between subsystem indexes and between subsystem indexes and other subsystems, and finally obtains the overall coupling coordination degree of the system.

4.1 Military-Local Coupling

4.1.1 Efficacy Function

The main body of equipment production process quality management is regarded as two subsystems, with n_i as the index number of the *ith* subsystem and O_{ij} as the target value of the j subsystem of the i subsystem $i = 1, 2; j = 1, 2, \cdots n_i$.

Use X_{ij} as the value of the jth index variable of the ith subsystem and U_{ij} as the efficacy function of the jth index of the ith subsystem:

$$U_{ij} = \begin{cases} U_{1ij} = \frac{1-e^{k_1(O_{ij}-X_{ij})}}{1+e^{k_1(O_{ij}-X_{ij})}} & \text{When } X_{ij} \text{ is a positive indicator.} \\ U_{2ij} = \frac{1-e^{k_2(X_{ij}-O_{ij})}}{1+e^{k_2(X_{ij}-O_{ij})}} & \text{When } X_{ij} \text{ is an inverse indicator.} \\ U_{3ij} = \frac{3-e^{k_3(X_{ij}-O_{ij})^2}}{1+e^{k_3(X_{ij}-O_{ij})^2}} & \text{When } X_{ij} \text{ is a moderate indicator.} \end{cases} \tag{1}$$

Where U_{ij} represents the contribution of the *jth* index of the *ith* subsystem to the efficiency of the equipment production process. The efficiency coefficient constructed according to (1) has the following characteristics: U_{ij} reflects the satisfaction of each subsystem index to achieve the goal. The closer U_{ij} is to -1, the most dissatisfied, and the closer U_{ij} are to $+1$, the most satisfied. When $X_{ij} = O_{ij}$, $U_{ij} = 0$ for both positive and negative indicators, indicating that the most basic requirements have been met; When $X_{ij} = O_{ij}$, for the moderate index $U_{ij} = 1$, it means that the target requirements are satisfied. The greater the U_{ij}, the greater the efficacy, the more satisfied, and $U_{ij} \in [-1, 1]$. k_1, k_2 and k_3 are coefficients, and constants greater than 0 can be taken. Its function is to adjust the sensitivity of the calculation result data. The greater the k value, the better the sensitivity of the result. Although the model itself has no special requirements for data, the target value, observed value or predicted value are greater than 0, and dimensionless processing should be carried out.

The effectiveness here represents the ability or efficiency of the quality management subject to achieve its objectives and can be used to reflect the coordinated development of the internal sub-system.

The coordinated development coefficients of subsystems are defined as:

$$U_2 = \sum_{j=1}^{n_i} \lambda_{ij} U_{ij} \quad i = 1, 2; j = 1, 2, \cdots n_i \tag{2}$$

$$\lambda_{ij} \text{ is the index weight, and } \sum_{j=1}^{n_i} \lambda_{ij} = 1.$$

4.1.2 Coupling Degree Function

Collaborative development between military and local areas can be investigated by analyzing the interaction among the elements of each subsystem and then calculating the coupling degree between the subsystems. The specific calculation is carried out through the following steps:

Step1 *Analysis of the Interaction between Indicators of Subsystems*

Let α_{ij}^{pq} be the coefficient of influence of the index of item j of subsystem i by the index of item q of subsystem p where $i, p = 1, 2; j = 1, 2, \cdots, n_i, q = 1, 2, \cdots, n_p$.

A can be obtained by expert scoring or correlation analysis, and $\alpha_{ij}^{pq} \in [-1, 1]$.

When $\alpha_{ij}^{pq} > 0$, it indicates positive influence and has to promote effect; When $\alpha_{ij}^{pq} < 0$, it indicates negative influence and inhibition; When $\alpha_{ij}^{pq} = 0$, it means no influence; In particular, $\alpha_{ij}^{pq} = 1$, and when $i \neq p, q \neq j, \alpha_{ij}^{pq} \neq \alpha_{pq}^{ij}$.

Step2 *Calculate the total impact of other subsystems on the indicators of each subsystem*

Use α_j^p to indicate the influence of all indexes of subsystem **p** on index j of subsystem i, which is recorded as:

$$\alpha_{ij}^p = \sum\nolimits_{q=1}^{n_p} \alpha_{ij}^{pq} X_{pq} \tag{3}$$

Where X_{pq} is the value of the q index variable of the p subsystem. $i, p = 1, 2; j = 1, 2, \cdots, n_i, q = 1, 2, \cdots, n_p$.

Then, the total impact of the *jth* index of other subsystems can be expressed as:

$$\alpha_{ij}^p = \sum\nolimits_{\substack{p = 1 \\ p \neq 1}}^{m} \sum\nolimits_{q=1}^{n_p} \alpha_{ij}^{pq} X_{pq} \tag{4}$$

Where, $i, p = 1, 2; j, m = 1, 2, \cdots, n_i, q = 1, 2, \cdots, n_p$.

Step3 *Coordinated development coefficient of indicators among subsystems*

Subsystem indexes are affected by other subsystems, that is, the coordinated development coefficient C_{ij} between subsystem indexes can be given by the following formula:

$$C_{ij} = \frac{\alpha_{ij}}{\sum\nolimits_{p=1}^{m} \sum\nolimits_{q=1}^{n_p} \alpha_{pq}} \tag{5}$$

Where, $i, p = 1, 2; j, m = 1, 2, \cdots, n_i, q = 1, 2, \cdots, n_p$.

Step4 *Coordinated development coefficient between subsystems*

Based on obtaining C_{ij}, the coordinated development coefficient C_2 between subsystems can be calculated.

$$C_2 = \sum\nolimits_{j=1}^{n_i} C_{ij} X_{ij} \tag{6}$$

Where, $i = 1, 2; j, m = 1, 2, \cdots, n_i$.

4.2 Military Local Coupling Cooperative Scheduling

4.2.1 Overall Coordinated Development Function of the Equipment Production System

The overall coordinated development index of the equipment production process is defined as T:

$$T = \sum\nolimits_{i=1}^{m} \beta_2 \left(\mu_{i_1} U_2 + \mu_{i_2} C_2\right) \tag{7}$$

All the index weights-tally with: $\sum_{i=1}^{m} \beta_i = 1, \mu_{i_1} + \mu_{i_2} = 1$.

4.2.2 Coupling Coordination Function

$$D = \sqrt{C_2 \times T} \tag{8}$$

Where D is the coupling co scheduling; C_2 is the coupling degree; T is the overall coordinated development index of the equipment production process.

Combined with the collaborative development coefficient within the subsystem of the equipment production process and the collaborative development coefficient between subsystems, the model can comprehensively investigate the collaborative development of military and local sides.

5 Conclusions

This paper discusses the synergy of equipment production process quality management organization, and creatively puts forward the SDS coupling coordination degree model, which includes the total influence of each subsystem index by other subsystems when calculating the coupling degree, which makes up for the defects of the traditional coupling coordination degree model and provides a theoretical basis for equipment production quality management, Make the synergy between military and local governments in the production process more scientific and efficient.

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