Analysis of the quality improvement path of supply chain management under the background of Industry 4.0

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Abstract: In view of the influence of the quality of supply chain management in the process of enterprise development, reducing the market competitiveness and customer satisfaction, this paper puts forward the path of improving the quality of supply chain management under the background of Industry 4.0. Through the analysis of the coordination structure dimension of supply chain management quality strategy level and the coordination structure dimension of executive level, it is determined that there are some problems in the process of supply chain management quality improvement, such as the failure of the incoming inspection department to inspect as required, the lack of supplier control ability, and the imperfection of supplier quality management process and mechanism. By strengthening the quality control of suppliers in key links and exploring the quality improvement path of supply chain management, market competitiveness and customer satisfaction can improve.

Keywords: background of Industry 4.0; supply chain management; quality improvement; path analysis.

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1   Introduction

With the development of the times, China's economy has developed rapidly. In order to improve the competitiveness of enterprises in the specialised market, more and more attention has been paid to the specialised division of labour. The focus of enterprise management is more on improving the core competitiveness. More and more enterprises begin to cooperate with supply chain partners to complete product development, production and sales. Compared with traditional enterprise production management, cooperation between enterprises and supply chain partners can maximise the economic benefits of enterprises on the basis of ensuring product quality (Rezaee, 2018). The management of product quality is the core of enterprise management. The upstream supplier of supply chain is not only the key link of effective quality management, but also the necessary way for enterprises to achieve economic benefits and sustainable development (Liu et al., 2017). Therefore, in the process of quality management of upstream suppliers, enterprises should not only consider the product quality of suppliers themselves, but also consider whether the products of suppliers match the production of enterprises. Only in this way can the product quality of enterprises be guaranteed on the premise of ensuring the product quality of suppliers. To sum up, enterprises must take the quality of supply chain management as the focus of production and operation.

Driven by the theory of division of labour, the production and operation of enterprises is no longer a simple transaction relationship between upstream and downstream, but a transformation from simple market transaction to supply chain transaction, which is a long development process (Nguyen, 2020). This transformation promotes the healthy competition among enterprises, which effectively promotes the development of social economy, and also provides power for innovation and development in various fields. The profit rate of an enterprise is the main body in its competitive relationship, which determines its survival and development. Of course, the existing supply chain market has various factors that affect the transaction instability. In order to avoid these unstable factors affecting the production and operation of enterprises, enterprises can avoid these risks by improving the quality of supply chain management. Specifically, enterprises will contact with more familiar upstream and downstream suppliers to form a supply chain through mergers and acquisitions or new plants, so as to manage and control the whole sales process of supply chain quality, ensure the initiative in the competitive market, and effectively control the quality of supply chain (Astuti et al., 2020). Under the background of economic globalisation, the competition among enterprises is becoming increasingly fierce, the global economy is developing rapidly, and the consumer demand is becoming increasingly diversified. To effectively improve the quality of supply chain management can enable enterprises to achieve sustainable operation and development in the increasingly fierce market environment.

In the background of Industry 4.0, in order to ensure the quality of products, enterprises must improve the quality management of supply chain. The management of supply chain quality should start from the selection of suppliers in the supply chain. In the whole upstream and downstream supply chain system, the quality of products developed and manufactured by suppliers should be effectively managed and controlled, so as to improve the quality of supply chain management (Carter et al., 2020). Effective

supply chain quality management enables every product produced by an enterprise to pass the certification smoothly. It not only meets the diversified needs of customers in the market, but also fundamentally improves the market competitiveness of the enterprise.

2 Case analysis

2.1 Data sources and respondents

Under the background of Industry 4.0, product production, sales and after-sales service are scattered in different enterprises of the supply chain, which is no longer realised in one enterprise. The quality of products is also guaranteed by all enterprises in the supply chain, to realise the operation of product quality in the whole supply chain.

Nowadays, supply chain management and control is not the internal quality control of a certain unit in the past, but the overall process of product quality formation in the whole supply chain. This paper chooses an important object in the supply chain to study whether its quality control method can affect the product quality of upstream and downstream enterprises and even the whole supply chain based on the whole enterprise. In order to obtain the latest analysis resources, it can send questionnaires to the senior managers who are familiar with quality management in the target enterprises.

The number of samples can be determined according to the relevant knowledge of statistical theory, because in the research of the quality improvement path of supply chain management, it needs to consume a lot of human, material and financial resources. Therefore, in the process of case analysis, questionnaire survey is used to reduce the consumption of resources. In the case analysis, 285 questionnaires are distributed and 208 questionnaires are returned, with a recovery rate of 72.98%.
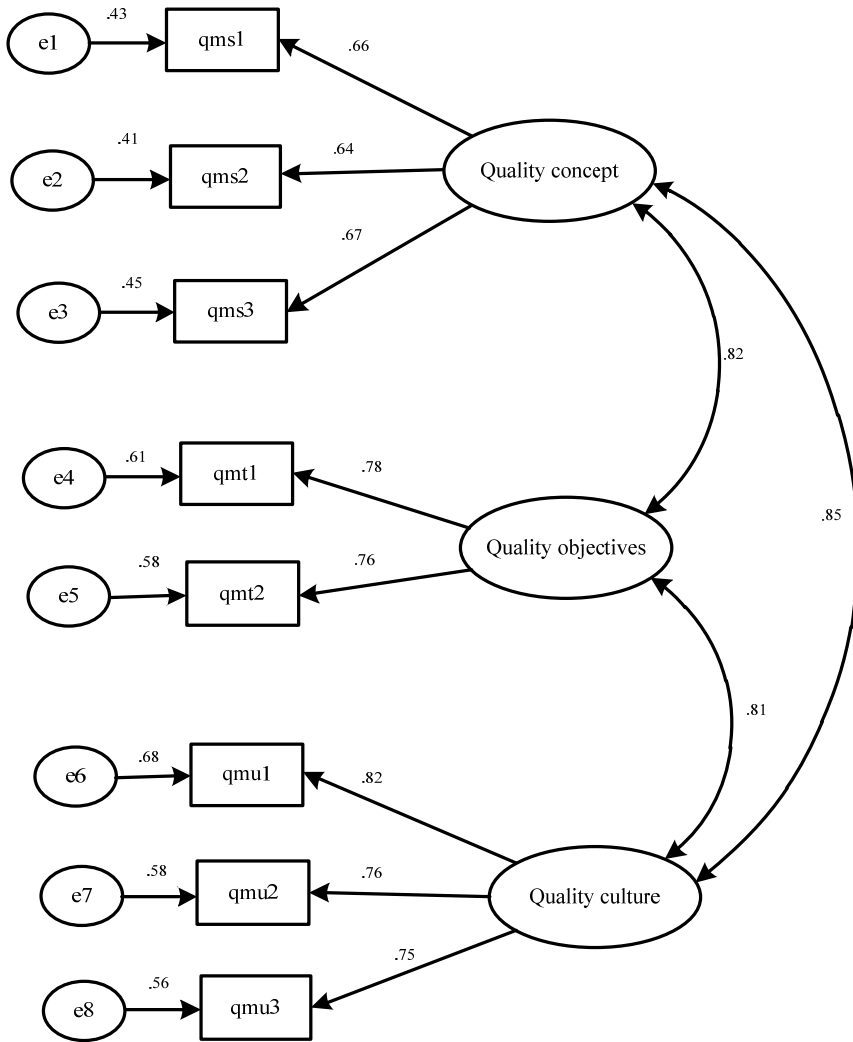
2.2 Result analysis

2.2.1 Dimension analysis of coordination structure in the strategy level of supply chain management quality

Under the background of Industry 4.0, according to the relevant theoretical derivation and exploratory factors, this paper analyses the relationship between different variables of supply chain management quality, and constructs a structural dimension model for the strategic level coordination of supply chain management quality. The model includes eight measurement variables, eight error terms and two external variables. The initial model of coordination structure dimension in the strategy level of supply chain management quality is shown in Figure 1.

Among them, e1–e8 represent different degrees of measurement variables, mainly according to the change of coordination structure dimension of strategic level in supply chain management, and its parameters also change constantly. qms1–qms3 represent different influence factors of supply chain management quality, and qmt1–qmt3 represent different quality objective parameters of supply chain management. In the dimension design of the model, the characteristic points of the coordination structure of the quality strategy layer of the enterprise supply chain management are considered, and a reasonable research dimension is designed according to the requirements of the characteristic points.

Figure 1   Initial model of coordination structure dimension in the strategy level of supply chain management quality

After statistical analysis, the initial model fitting indicators of coordination structure dimension in the strategy level of supply chain management quality are shown in Table 1.

It can be seen from the results in Table 1 that the CMIN/DF value of the initial model of the coordination structure dimension in the strategy level of supply chain management quality is 5.778, which is greater than 3, indicating that the fitting effect of the initial model of the coordination structure dimension in the strategy level of supply chain management quality is not ideal. If the AGFI value is adjusted to 0.740, which is less than the evaluation standard of 0.9, the fitting effect of the model is still not very good; GFI index, NFI index and CFI index are 877, 0.836 and 0.857 respectively, which are close to the evaluation standard. The fitting result of the model is basically acceptable.

The RMR index value is 0.052, which is close to the evaluation standard. The fitting effect of the model is acceptable. In terms of RMSEA index, the fitting effect of the model is not very good. From all the above fitting indicators, the overall fitting effect of the initial model of coordination structure dimension in the strategy level of supply chain management quality is not ideal, and needs to be further optimised.

Table 1 Initial model fitting index value of coordination structure dimension in the strategy level of supply chain management quality

Fitting index	Evaluating indicator	Initial model
Mean square root of residuals (RMR)	< 0.05	0.052
Chi square degree of freedom (Cmin/DF)	< 3	5.778
Goodness of fit index (GFI)	> 0.90	0.877
Goodness of fit index (AGFI)	> 0.90	0.740
PGFI	> 0.5	0.414
Mean square root of approximate residuals (RMSEA)	< 0.08	0.174
Standard fit index (NFI)	> 0.090	0.836
Comparative fit index (CFI)	> 0.90	0.857

According to the correction index provided by AMOS17.0, the initial model of coordination structure dimension in the strategy level of supply chain management quality is modified, and the correction index limit of chi square value difference is set to be greater than 8. The modified initial model of coordination structure dimension in the strategy level of supply chain management quality is shown in Figure 2.
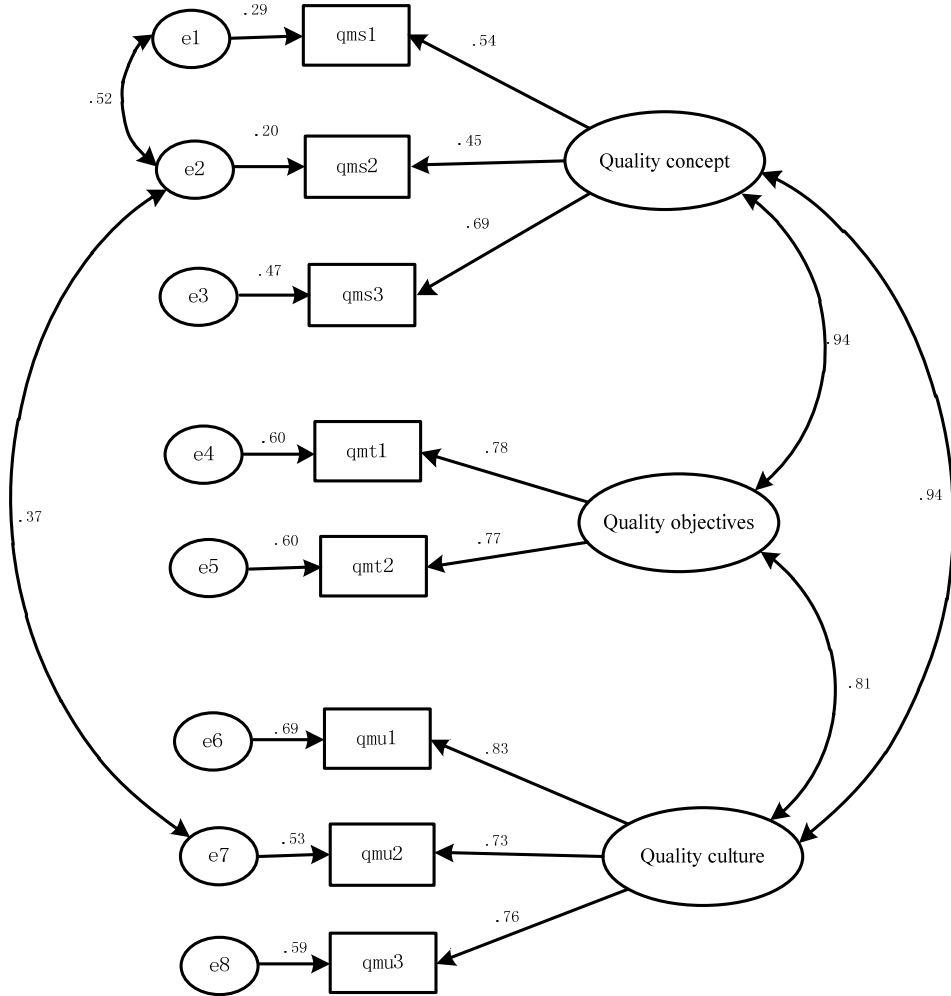
The revised coordination structure dimension of supply chain management quality strategy layer takes into account the objectives of different dimensions, and expands different influencing parameters to different degrees, so as to improve the quality of supply chain management.

Table 2 The fitting index of the initial modified model for coordination structure dimension in the strategy level of supply chain management quality

| Fitting index	Evaluation criterion	Initial model	Modified model	Judgement result
Mean square root of residuals (RMR)	< 0.05	0.052	0.028	Ideal
Chi square degree of freedom (Cmin/DF)	< 3	5.778	2.369	Ideal
Goodness of fit index (GFI)	> 0.90	0.877	0.947	Ideal
Goodness of fit index (AGFI)	> 0.90	0.740	0.873	Acceptable
PGFI	> 0.5	0.414	0.395	Acceptable
Mean square root of approximate residuals (RMSEA)	< 0.08	0.174	0.093	Acceptable
Standard fit index (NFI)	> 0.90	0.836	0.941	Ideal
Comparative fit index (CFI)	> 0.90	0.857	0.964	Ideal

After the initial model of coordination structure dimension in the strategy level of supply chain management quality is revised, the fitting index of the revised model is calculated again, and the results are shown in Table 2.

Figure 2   The preliminary revision model of coordination structure dimension in the strategy level of supply chain management quality

It can be seen from the results in Table 2 that the CMIN/DF index of the preliminary correction model of coordination structure dimension in the strategy level of supply chain management quality is 2.369, which has a relatively ideal fitting effect. The AGFI index of the model is 0.873, and the fitting result is acceptable. The GFI index, NFI index and CFI index are 0.947, 0.941 and 0.964 respectively. The fitting effect of the model is very good, and the RMR index value is 0.028, the fitting index the model is ideal. The RMSEA index value is in the acceptable range. It can be seen from the above index results that the overall fitting effect of the initial correction model of coordination structure dimension in the strategy level of supply chain management quality is relatively ideal. The modified model is accepted as the final model of coordination structure dimension in the strategy level of supply chain management quality.

Figure 3　Initial model of coordination structure dimension in the executive level of supply chain management quality
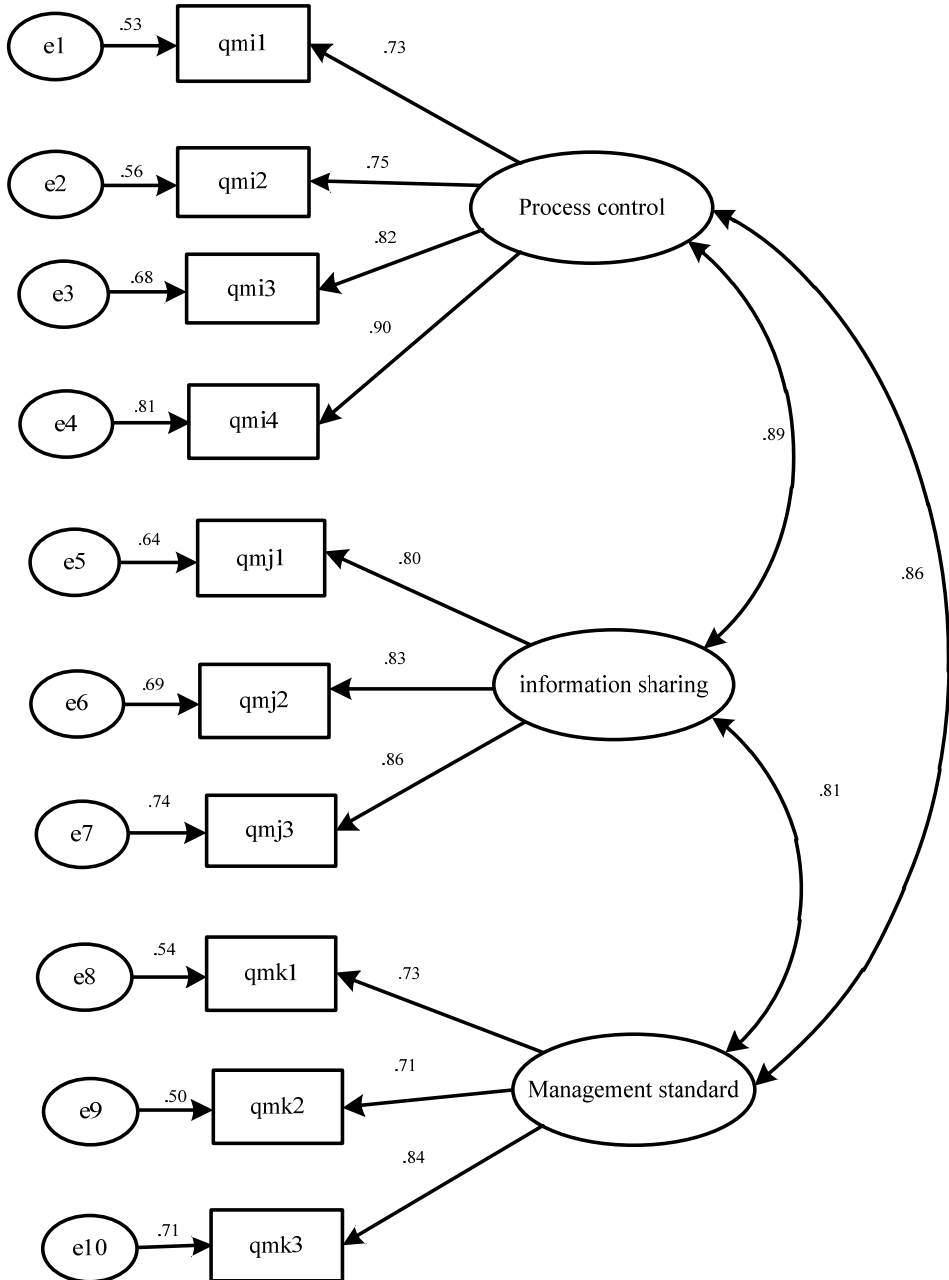
2.2.2 *Dimension analysis of coordination structure in the executive level of supply chain management quality*

In the implementation layer of supply chain management quality, coordination factors include the establishment and implementation of norms, information sharing between enterprises and the control of management quality process. Whether these three dimensions have certain reliability in the improvement of supply chain management quality needs to be verified by confirmatory factor analysis (Shou et al., 2020).

Under the background of Industry 4.0, according to the relevant theoretical derivation and exploratory factors, this paper analyses the relationship between different variables of supply chain management quality, and constructs a coordination structure dimension model in the executive level of supply chain management quality. The model includes ten measurement variables, ten error terms and three external variables. The initial model of coordination structure dimension in the executive level of supply chain management quality is shown in Figure 3.

By means of statistical analysis, the fitting indexes of the initial model of coordination structure dimension in the executive level of supply chain management quality are calculated, and the results are shown in Table 3.

Table 3   Fitting indicators of the initial model for coordination structure dimension in the executive level of supply chain management quality

Fitting index	Evaluation criterion	Initial model
Mean square root of residuals (RMR)	< 0.05	0.033
Chi square degree of freedom (Cmin/DF)	< 3	1.635
Goodness of fit index (GFI)	> 0.90	0.943
Goodness of fit index (AGFI)	> 0.90	0.902
PGFI	> 0.5	0.549
Mean square root of approximate residuals (RMSEA)	< 0.08	0.063
Standard fit index (NFI)	> 0.90	0.952
Comparative fit index (CFI)	> 0.90	0.981

It can be seen from the results in Table 3 that the initial model of coordination structure dimension in the execution level of supply chain management quality can show the ideal rated fitting indicators in all the fitting effect indicators. However, according to the relevant suggestions of model correction indicators, the fitting effect is better after the model is modified, and the modified initial model of coordination structure dimension in the execution level of supply chain management quality is shown in Figure 4.

After the initial model of coordination structure dimension in the executive level of supply chain management quality is revised, the model fitting index is calculated again, and the results are shown in Table 4.

It can be seen from the results in Table 4 that all the fitting indexes of the initial modification model for coordination structure dimension in the executive level of supply chain management quality have very ideal fitting effect. The revised coordination structure dimension model of supply chain management quality implementation layer is taken as the final coordination structure dimension model of supply chain management quality implementation layer.

Figure 4   Preliminary revision model of coordination structure dimension in the executive level of supply chain management quality
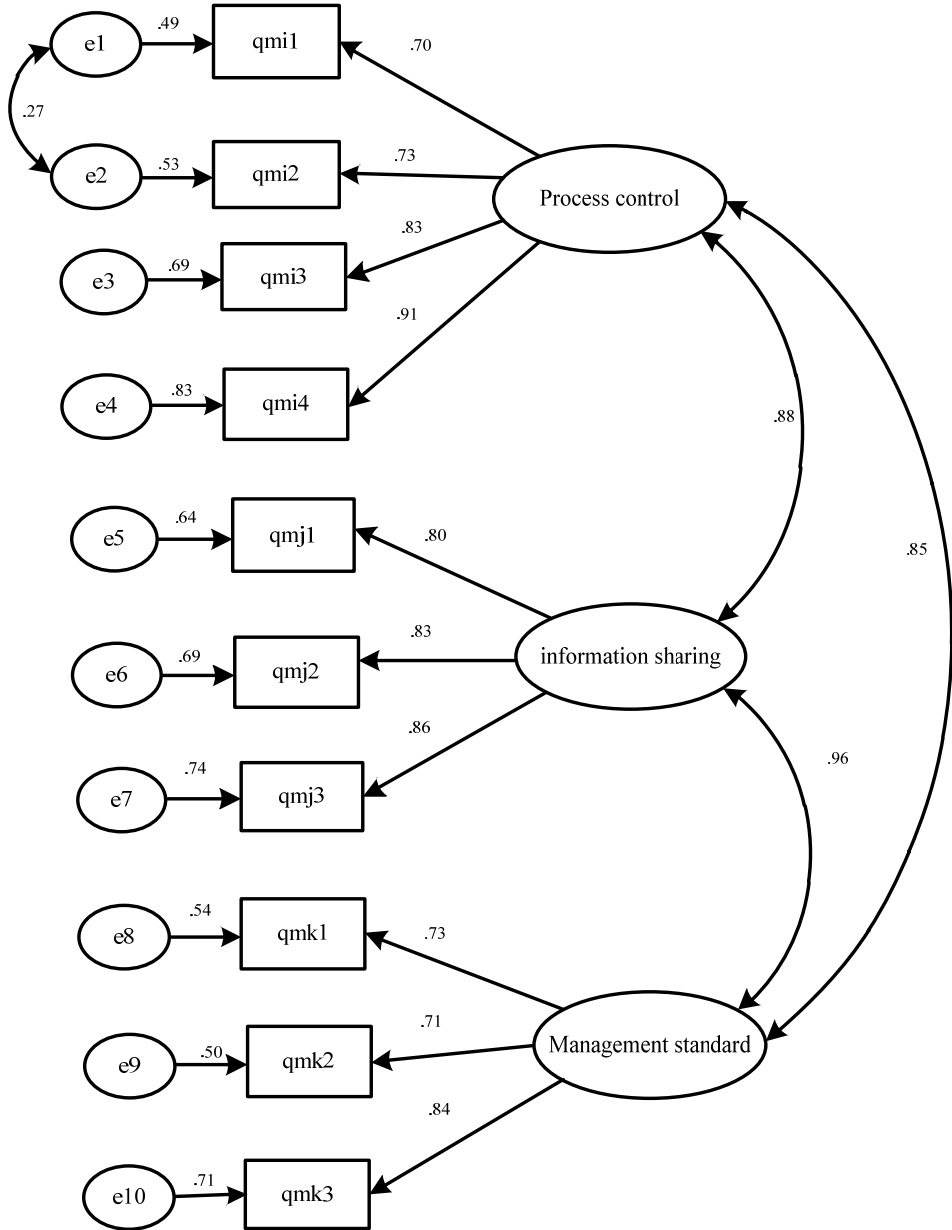
Table 4   Fitting index of the initial modified model for coordination structure dimension in the executive level of supply chain management quality

Fitting index	Evaluation criterion	Initial model	Modified model	Judgement result
Mean square root of residuals (RMR)	< 0.05	0.033	0.031	Ideal
Chi square degree of freedom (Cmin/DF)	< 3	1.635	1.382	Ideal
Goodness of fit index (GFI)	> 0.90	0.943	0.953	Ideal
Goodness of fit index (AGFI)	> 0.90	0.902	0.916	Ideal
PGFI	> 0.5	0.549	0.537	Ideal
Mean square root of approximate residuals (RMSEA)	< 0.08	0.063	0.049	Ideal
Standard fit index (NFI)	> 0.90	0.952	0.961	Ideal
Comparative fit index (CFI)	> 0.90	0.981	0.989	Ideal

3   Problems in improving the quality of supply chain management

According to the results of case analysis, the following problems are found in the improvement of supply chain management quality, as follows.

3.1   The supplier quality management process and mechanism are not perfect

At present, the enterprise supplier quality management process and mechanism is not perfect (Fraser et al., 2020), there are the following problems: the enthusiasm of incoming quality testing is not high, resulting in the problem products can not be solved in time; in addition, there is not strictly abide by the testing standards for testing, resulting in inaccurate testing results and other problems.

3.1.1   The incoming inspection department fails to conduct accurate inspection as required

Generally speaking, quality inspection is needed at the beginning of the immature project. Customers usually have their own inspection standards for products, but in the process of new product development and development, researchers will add some regulations beyond the inspection standards, which make the work of the incoming material inspection department more difficult. This greatly affects the inspection accuracy of the incoming inspection department (Seuring et al., 2021). The unqualified materials will affect the quality of products and eventually lead to complaints on the production line. If the incoming inspection department fails to carry out the accurate inspection according to the regulations, it will also cause some qualified products to be unqualified, resulting in disputes between the enterprise and the supplier due to the return of goods, affecting the economic interests of both parties.

3.1.2 Insufficient supplier control capability

The incoming inspection department is mainly responsible for the supplier's product quality inspection, and timely communicates with the supplier for feedback on the products with test results, so that the unqualified products can be solved and improved in time. However, in the actual operation process, the incoming inspection department has the problem of insufficient control ability to the supplier, which makes the supplier's products have not been well controlled. The lack of control ability of suppliers is mainly manifested in the following two aspects: firstly, the incoming inspection department does not participate in the process of selecting suppliers at the initial stage, resulting in low participation in supplier quality management and affecting the later control ability; secondly, when the incoming inspection department inspects the unqualified products, it does not put forward reasonable suggestions to the supplier's quality management department, but directly programs to feed back the unqualified information. For the suppliers who are unwilling to improve the quality problems, effective control measures are not taken in time (Baier et al., 2020).

3.2 The quality control effect of key links is poor

The battery material industry generally carries out production and operation activities around the project, and regards the project as the centre of production and operation. Therefore, the management and control of suppliers should touch every stage of the project, and never neglect any link. It is particularly important for the raw material supply and quality management of raw materials, especially new products (Li et al., 2020). The current situation is due to the company for each project is not comprehensive and rigorous quality management, failed to form a systematic procedure with rules. And each person in charge of the project has its own way of work, the management of the project is relatively loose, there is no systematic procedure to follow to refer to, resulting in an increase in the possibility of problems. Taking the company's very important products in this year as an example, most of its quality problems are caused by suppliers in material research and development, commissioning and mass production. The quality control effect of supply chain in key links is shown in Figure 5.

3.2.1 Limited involvement of suppliers in new product development

Because the company has not formed large-scale production, there is relatively little communication with suppliers when developing new products. Generally, the designers of the research and development department make their own decisions without considering the specific situations that will appear in the production process (Kashav et al., 2020). Therefore, the suppliers may not have a thorough understanding of the designer's concept, nor can they communicate with each other in a timely and sufficient manner, resulting in the special situation of design in mass production.

If the company can communicate effectively with the supplier in the design of new products for many times, the supplier has rich industry experience for many years, and can bring some good suggestions for the enterprise in design and production, so that some design problems can be found before mass production, so as to avoid causing a lot of losses. Generally, small problems in the design process cannot be found in the debugging stage, but they are exposed completely in the mass production process, and

even magnified many times, so it is not so easy to solve them again. Changing the design scheme and replacing the raw materials cause great losses.

Figure 5   The quality control effect of supply chain in key links is not ideal (see online version for colours)
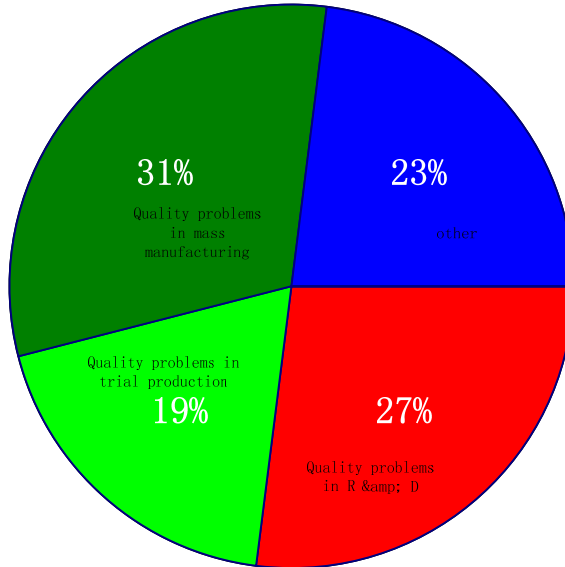
3.2.2   *There is no sound judgement and treatment plan for unqualified products*

Once the company finds out the unqualified products in the production inspection, it needs to take action immediately, organise relevant personnel to audit the unqualified products, and find out the fundamental factors. If the product is unqualified due to the raw materials, then according to the established requirements, it should immediately supervise the supplier to improve the product quality through the supplier. If the enterprise's own production process has a very serious problem (Liu et al., 2020), it is required to adjust, optimise and deal with the current production mode immediately. At present, the company has not formed a perfect system to judge and solve the unqualified products, and there are still many problems. There is no fixed post and technical personnel to analyse and detect the unqualified products, resulting in the quality problems can not be dealt with in time.

4   Quality improvement path of supply chain management

To create an effective supply chain, it is needed to adjust and merge the internal activities of the supply chain, coordinate the data transmission in the whole system, and carry out careful planning and coordination between suppliers and customers as well as all the demand parts of the whole supply chain. High quality and high trust supplier is the key link of the whole supply chain (Shakil et al., 2020). The performance of supplier's
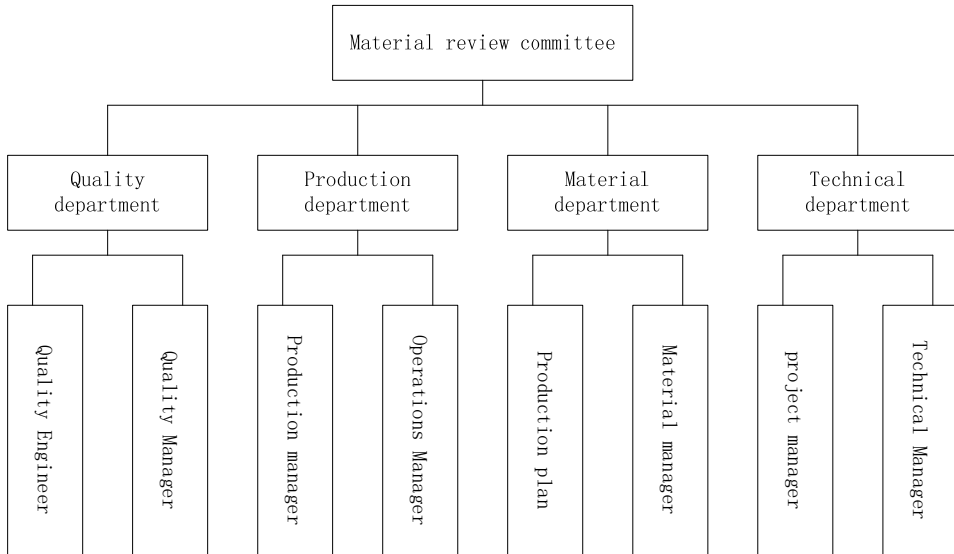
effective operation is high-quality transportation products and services. At present, one of the commercial competitive advantages is good supplier relationship maintenance.

4.1 To improve the related process and mechanism of supplier quality management

4.1.1 To improve the operation mechanism of procurement review committee

In terms of procurement, the company has formed a specific process, which plays a certain role in the management of unqualified products, and has a large space for improvement. For example, the feedback is not clear enough, the approval time is long, so it is necessary for the company to adjust the procurement. The quality engineer should review the unqualified products found by the inspectors during the feeding process. In the review process, the review committee should be composed of the department managers of each important link. However, when problems occur, the directors of each department first participate in the review, which leads to many times that the leaders can not fully understand the situation (Han et al., 2020). The composition of the material review committee should preferably be in the form of documents, which takes effect after the company's review and approval. In this way, the quality engineer can have a basis for holding the review meeting in the future, and also supervise the leaders of relevant departments to participate in the review meeting in time, as shown in Figure 6.

Figure 6 Operation mechanism of procurement review committee

Material review committee

- Quality department
  - Quality Engineer
  - Quality Manager
- Production department
  - Production manager
  - Operations Manager
- Material department
  - Production plan
  - Material manager
- Technical department
  - project manager
  - Technical Manager

When the company approves the procedure documents, the quality engineer has a system to be based on when holding the review meeting to provide work guarantee for the department leaders to participate in the material review meeting (Yaziz, 2020).

4.1.2   To improve the control procedure of incoming inspection

When inspecting the first batch of incoming materials, the incoming inspection personnel should consider the actual needs of customers and the standard sample format. If there is no standard specification, they should contact the project director at the first time, and then sign and issue the standard sample of products after confirmation. If there are some situations between qualified and unqualified which are not easy to define, the inspectors should contact the supplier immediately to confirm the final quality with the end customer, so as to avoid unnecessary trouble between the enterprise and the supplier (Alkahtani et al., 2021).

In the production process can not avoid emergency, can not timely inspection and acceptance of raw materials and auxiliary materials, the appropriate approach is to attach the emergency production logo to each incoming material box, and then put into production. However, even if it is put into production in an emergency, it is necessary to carry out the inspection work on the materials after that, and make detailed records on the batch number, date, quantity, use place, etc. (Zhang, 2019). The incoming inspection personnel shall strictly monitor the quality of the raw materials put into production in an emergency. Once the quality of the products is found to be unqualified, the replacement of materials should be stopped immediately and registered for the record.

4.2   To strengthen collaborative quality control with suppliers in key links

4.2.1   To strengthen collaborative quality control in R&D phase

At present, there is a lack of active communication between the company and suppliers. In the development and design stage of many new projects, this kind of communication is not smooth, which causes the improper selection of raw materials, and bring adverse effects to the work of both the company and suppliers (Choi et al., 2019). In order to strengthen the management and control of suppliers, the company should first start in the research and development phase and effectively control the product quality with suppliers.

The company should invite suppliers to participate in the early design and development stage of new projects, comprehensively consider the resources and production strength of the enterprise itself, and inform the suppliers of the requirements of its new products on the premise of the technical indicators required by customers. In addition, the supplier has many years of practical experience, can provide some feasible suggestions to help enterprises improve the comprehensive strength of products, reduce the cost of investment. This practice not only bring about continuous improvement of product quality and ensure the requirements of enterprises in the production process, but also show great sincerity of enterprises in cooperation with suppliers (Xu et al., 2021). In the same way, suppliers can fully absorb and accept the design ideas and quality standards of new products through the above ways, and then better complete the production of products according to the process standards. This is the so-called 'pay close attention to the management at the beginning' to ensure the final high-quality products.

4.2.2   To strengthen collaborative quality control in manufacturing process

In the process of mass production, the main focus of supplier control is the inspection of the first batch of incoming materials and the inspection of future batch incoming

materials. In the process of production and manufacturing, the unity and cooperation in the manufacturing process should be enhanced to control the quality of products.

In the design, research and distribution, experimental production and feeding links, the company carries out quality control, but the number of products in the design and experimental production link is not very large, so it is easier to control, but the mass production is on the contrary, which means that collaborative management is particularly important in the formal production (Oscar et al., 2019). In view of the above research and analysis, after dealing with the quality problems in the production process, the company should form a written form and send it to the supplier for further negotiation of effective solutions.

Table 5   Quality problem analysis of supply chain management

Management quality issues	Frequency of occurrence	Potential key reasons	Improvement plan
The workshop lacks dust-proof facilities	19	Lack of dust prevention facilities in supply chain workshop environment.	Check the dust-proof facilities for failure
Bad materials	31	Bad incoming materials in supply chain	Strengthen incoming material inspection; improve the proficiency of the staff.
The impurity content of the material exceeds the standard	37	Insufficient product design or equipment capability	Improve the process and equipment to achieve 100% inspection.
Contamination of materials due to improper operation	53	Improper operation method of supplier's operator	Transfer the production process of materials to the closed workshop and replace the cleaning equipment regularly.
Unqualified key parameters	135	Product design problems	Design improvement of material production process.

This paper analyses the quality problems in the production process of the company's supply chain. The final inspection results should be fed back to the suppliers in the form of reports, so as to make the most effective coordination and give the corresponding countermeasures in improving the quality.

5   Analysis on the effect of supply chain management quality improvement

In order to verify the quality improvement effect of supply chain management under the background of Industry 4.0, this paper takes a small and medium-sized logistics enterprise under the background of Industry 4.0 as the research object, analyses the management status of the enterprise, and applies the quality improvement method of supply chain management designed in this paper to the enterprise, tests the application effect of the enterprise for six months, and shows the effect, In order to highlight the effectiveness of the promotion path, the sample enterprises are divided into four parts,

among which, department 1 applies the supply chain management path of this paper, and the other three departments are used as the control group.

The four parts of the sample enterprise manage the enterprise supply chain respectively, and the management efficiency results are shown in Figure 7.

Figure 7   Comparative analysis of supply chain management efficiency of different departments (see online version for colours)
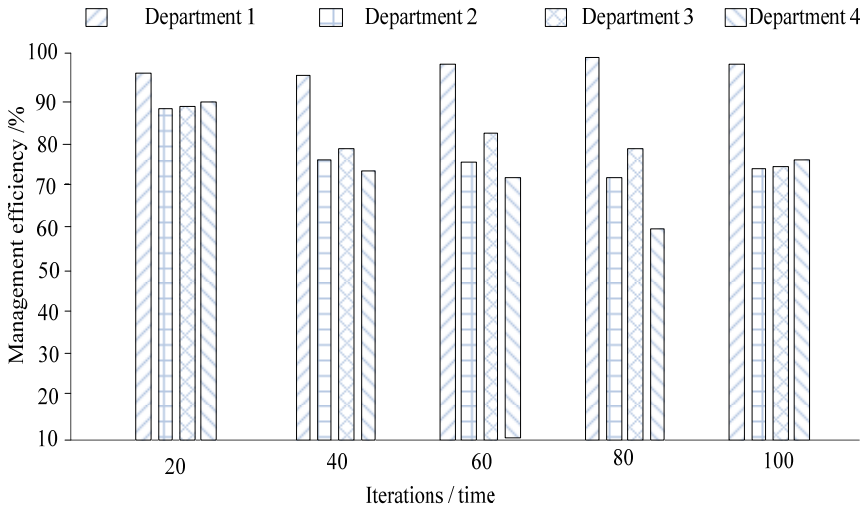
By analysing the experimental results in Figure 7, we can see that with the continuous change of experimental times, the four parts of the sample enterprises manage the enterprise supply chain respectively, and the management efficiency is different. Among them, department 1 which adopts the promotion path in this paper has the highest efficiency of supply chain management, and is always higher than 90%, while the management efficiency of the other three departments is always lower than that of the department which adopts the promotion path in this paper. It can be seen that the promotion path in this paper can improve the efficiency of supply chain management.

Table 6   Supply chain management cost analysis of sample management departments (wan yuan)

Iterations/times	Department 1	Department 2	Department 3	Department 4
10	12	20	28	19
20	11	22	30	18
30	12	23	32	18
40	12	23	35	19
50	13	26	35	19
60	11	28	35	19
70	11	30	34	20
80	13	32	32	20
90	12	34	35	19

In the enterprise supply chain management, the management cost of the supply chain is also one of the important indicators. Therefore, this paper analyses the management cost of the above four management departments for one month, and the results are shown in Table 6.

By analysing the data in Table 6, it can be seen that with the increasing number of experiments, the cost of the four departments of the sample enterprise's supply chain management for one month has changed. Among them, the management cost of department 1 is the lowest among the four parts, and the highest is about 130,000 yuan, while the management cost of the other three departments is always higher than that of department 1. In particular, the management cost of department 3 is fast, which is not suitable for enterprise supply chain management.

6   Conclusions

This paper puts forward the quality improvement path of supply chain management under the background of Industry 4.0. Through case analysis, this paper analyses the different dimensions of supply chain management quality, and finds out the problems existing in the process of improving supply chain management quality. By improving the process and mechanism of supplier quality management, strengthening the quality control of suppliers in key links, this paper explores the path of improving supply chain management quality, so as to improve market competitiveness and customer satisfaction.

Acknowledgements

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